THE OHIO JOURNAL OF SCIENCE

VOL. 60 JANUARY, 1960 No. 1

STUDY OF PREROOSTING BEHAVIOR IN CAPTIVE REDWING BLACKBIRDS

MILDRED MISKIMEN†

Miami University, Oxford, Ohio

The original objectives of this study were (1) to determine the relation of light and roosting activities, (2) to study effects of weather changes upon overt behavior and (3) to observe seasonal changes in activity of the Redwing Blackbird, *Agelaius phoeniceus*. These objectives were not attained because escape of the flock forced premature termination of the study, but experience gained in management of the captive flock, and insight into the problems studied, are matters of possible value to others working in the field.

The study was conducted on the campus of Miami University at Oxford, Ohio, from December, 1956 through December, 1957. Equipment and supplies were provided by the Margaret B. and William G. Pickrel Fund for Faculty Research at Miami University. I am grateful to Provost C. W. Kreger for his part in making these funds available and for his encouragement during the work.

Fifteen immature male Redwing Blackbirds were confined in a wire mesh cage 10 ft × 10 ft × 30 ft on the Miami University Campus. The cage sits with its long axis north and south, with woods on the east side and the two ends, and university buildings near by the west side. One building, occupied by a rifle range, was about 25 ft from the southwest corner of the cage. Food shelters with open sides and roosting shelters which could be entered through holes were located at each end of the cage, about five ft from the ground. Food was provided in chick feeders, and water for drinking and bathing was placed in a flat pan on the ground. Both food and water were continually available.

The cage was made of three-quarter in. wire mesh stretched over a framework of 4 in. × 4 in. wooden posts set at five-ft intervals along the 30-ft sides, connected at the tops by longitudinal and cross pieces. The ends of the cage received further support from the shelter boxes which were firmly fastened to the uprights. A walk-in door gave access to the cage and small openings on the outside of the shelter boxes permitted replenishing food and cleaning without entering the cage. The wire mesh was extended two ft below the surface of the ground to prevent rodents tunneling. The only rodent trouble came from immature chipmunks which could enter through the small mesh.

The size and design of the cage proved well-suited to their purpose. The birds had room to fly freely, yet remained within easy observation distance. The greatest fault with the cage was that the wire mesh was easily broken by vandals and the flock was lost. Later an eight-ft fence of heavy expanding metal was erected around the cage, so future flocks will be relatively safer.

I estimated the overall activity of the flock by counting the complete flights from one end of the cage to the other. Flights beginning or ending other than at one end of the cage were not counted. During periods of intense activity I

---

†Present address: Douglass College, Rutgers University, New Brunswick, N. J.

could not keep notes while counting flights so temporary records were made on recording tape, recording my voice as I counted the flights. Later the records were played back and transcribed to paper by hand. I also kept a record of light intensity at five min. intervals, using a photographic light meter directed toward the sky overhead. Temperature, cloud, and precipitation records were kept throughout the study. Dewpoint records were discontinued when the temperatures fell below freezing, and wind records were discontinued after experience showed that, due to the sheltered position of the cage, direct winds rarely affected the birds. Observations were made from an automobile or from a sentry box placed for the purpose about 30 ft from the cage.

Although the study could not be completed, the few data collected contain useful information and so are presented below.

TABLE 1

At 28 of 33 observations, 84.8%, activity began when light intensity was below 70 ft-c

Light at which activity began	Times Observed
29 to 20 ft-c	4
39 to 30 ft-c	7
49 to 40 ft-c	3
59 to 50 ft-c	5
69 to 60 ft-c	5
79 to 70 ft-c	4
89 to 80 ft-c	1
120 to 100 ft-c	2

TABLE 2

At 29 of 39 observations, 74%, maximum activity was between 5 and 20 ft-c

Light during 5 minutes of maximum activity	Times observed
9 to 5 ft-c	10
14 to 10 ft-c	8
19 to 15 ft-c	11
24 to 20 ft-c	4
29 to 25 ft-c	2
34 to 30 ft-c	2
39 to 35 ft-c	1
60 to 45 ft-c	1

Flight, in the captive Redwing Blackbird flock, was largely restricted to morning and evening periods, with very little flight during the middle of the day. The morning period began at dawn and continued until the sun was high. Evening flights began when the sun was low and continued until all had roosted. During these two periods the birds repeatedly flew the length of the cage, often in rapid succession, with interruptions to feed and drink. For this study I chose to make observations during the evening flight periods for the first two weeks of each month. This would enable me to observe not only light influence but also weather-influenced changes and seasonal changes in rate of activity. After the February observations, the cage unfortunately became damaged, thereby allowing all the birds but one to escape. Failing to trap more birds during spring migration, I made a few additional observations of the solitary bird during the summer and again in December. These latter data are too few to be significant but they are included as a matter of interest.

Initiation of evening flight period.—On some occasions evening flights had already begun when I reached the cage, but of the 33 times beginning of flight activity was observed the light intensity was below 80 ft-c on 29 evenings, 88 percent of the total (table 1). One of the exceptions was on February 10, when evening flights began while light intensity was about 200 ft-c. On that day a wild male Redwing Blackbird was present, flying back and forth over the cage, stimulating the captives to extreme agitation. Ten minutes later the light reading was 50 ft-c. Apparently activity initiated by the arrival of the wild bird merged with the usual preroosting behavior, which proceeded as usual after the wild bird flew away. On the other three evenings, when flights began at unusually high light intensity, I could see no wild redwings from my position in the car but I

suspected their presence from the behavior of the caged birds. Evidence that reduced light intensity was a major factor in initiating evening flight activities in the caged Redwings is very strong.

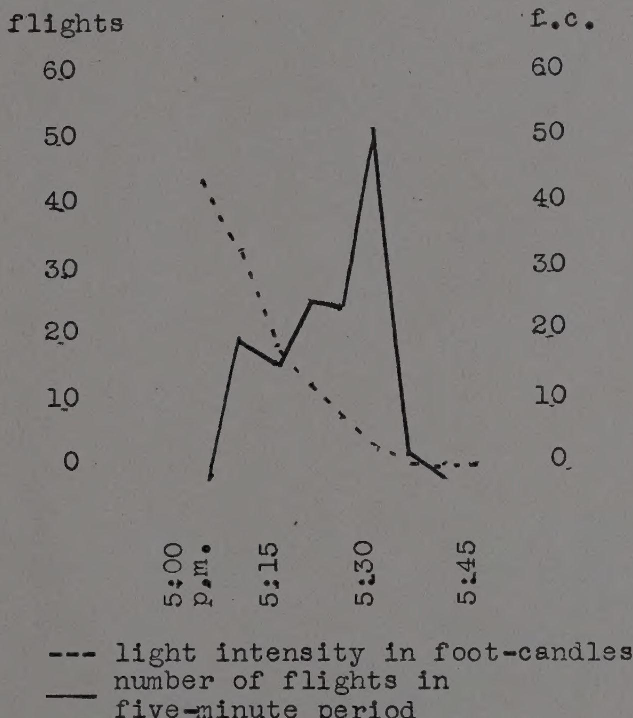


FIGURE 1. Comparison of rate of activity with light intensity. December 7, 1956.

Period of greatest activity.—Figure 1 shows a sample graph of evening flight frequency compared with light intensity. The graph was made from data recorded on December 7, 1956 and was chosen because it is typical of the activity pattern. From complete inactivity, flights increased in frequency to a peak, then declined rapidly as the birds entered the roost. Table 2 shows the light intensities at which this peak occurred in terms of numbers of flights in five-min periods. At 29 of the 39 observation periods this activity peak occurred when the light was between 9 and 20 ft-c. More data should be available before drawing any firm conclusions as to light influence in this case. Observations of the solitary bird made in the summer did not show the same consistency in the pattern of activity; therefore, social facilitation must be considered as a possible factor in determining the activity pattern.

Entering the roost.—The caged birds did not enter the roosts until the light was below 20 ft-c (table 3). This applied not only to the prepared shelters but to roosts in brush or on tops of shelters that were used in mild weather. The first birds to enter the roosts did not stay but flew out again. Usually several minutes elapsed between the time of first entry and the time roosting was com-

pleted. The interval was occupied by competition for roosting places, sometimes with intense aggressive behavior. Short feeding intervals were noted in some cases. I made no study of possible roosting territory.

Completion of roosting.—In all cases observed activity ended at light intensities varying from 1 to 5 ft-c (table 4). This seemed to be determined by light from the sky as recorded by the light meter rather than by total visibility. On evenings when snow covered the ground or when there was bright moonlight, the birds roosted while area visibility was very good; but on other evenings when the sky was relatively brighter, they were active after visibility was poor. Apparently the light intensity of the sky rather than general visibility of objects around them induced roosting and cessation of activity in these birds.

TABLE 3

At 19 of 39 observations, 48.7%, the first birds entered the roost at light intensity between 5 and 1 ft-c

Light at which first enterest roost	Times observed
20 to 16 ft-c	4
15 to 11 ft-c	10
6 to 10 ft-c	5
5 to 1 ft-c	19

TABLE 4

At 18 of 39 observations, 46%, roosting was completed at 2 ft-c

Lights at which activity stopped	Times observed
5 ft-c	4
4 ft-c	6
3 ft-c	6
2 ft-c	18

Seasonal variation in activity.—Table 5 shows the amount of activity as measured by counts of complete flights from end to end of the cage in different months. Records made in December, January, and February show increasing activity as the season progressed. Omitted from this record are the data for February 10, the day the wild Redwing stimulated the caged birds to unusual activity. On that day the total of counts recorded was 1029. Since this figure was far above the next highest count, 580, I thought best to exclude it from the calculations, as its inclusion distorts the gradual seasonal increase in activity shown by the other figures. Added to the table as a matter of interest are the data recorded at the few summer and winter observations made of the solitary Redwing. While no conclusions can be drawn from so few figures, they do suggest (1) a great increase in flight activity during summer and a subsequent decrease in winter, and (2) a great increase in activity of a solitary bird as compared with a flock. On several occasions a wild female Redwing perched on or near the cage containing the captive male. On each occasion the male stopped other activities and perched quietly until the female flew away. These observations of the solitary bird suggest that further study of flocks and flock size may be profitable.

Weather observations.—Effects of weather changes upon number of flights made by the birds under observation could not be determined by the methods used in this study. The data on quality of light as determined by cloudy vs. clear or partly clear sky, and the effect upon activity indicate that on days of complete overcast there was higher frequency of counts below the mean for the period, and that the reverse was true on clear or partly clear days. Analysis of these data gives a Chi-square value of 1.56, which is not statistically significant at the one percent level. No tentative conclusions can be reached without many more data of these kinds.

Beginnings of adult display.—Vocalization at first consisted of a variety of call notes. On December 8, 1956 I made the first note of an imperfect song resembling the adult ko-ka-ree song. The first full, typical ko-ka-ree song was

noted on January 10, 1957 at noontime on a day of bright sunshine and snow cover. The full song was first heard during evening activity on February 3, 1957, and thereafter it was heard with increasing frequency. Display of epaulets was first observed on December 7, 1956, and thereafter was seen daily with or without accompanying song.

TABLE 5

Seasonal record of total numbers of flights made by the captive Redwing Blackbirds during evening activity periods

A Redwing flock	Total flights	Number of observations	Maximum per day	Minimum per day	Mean	$\pm \sigma$
Dec. 5–16 1956	1835	12	304	27	152.9	89.4
Jan. 1–14 1957	3107	13	468	59	239.0	136.7
Feb. 2–17 1957	4685	13	580	135	362.7	138.9
Totals	9627	38	580	27	253.3	196.2
A solitary Redwing						
July-Aug. 1957	2227	8	541	90	278	159.2
Dec. 1957	268	5	174	5	54	64.5

Food preferences.—Although the birds were trapped by using shelled corn as bait, they refused to eat shelled corn in the cage as long as other food was available. During the first weeks oats and cracked corn were preferred to other food, but after the birds learned to eat sunflower seeds they were taken in increasing quantities. Oats and cracked corn were eaten in varying quantities throughout the study, but wheat, mixed songbird seed and prepared protein feed for poultry were never eaten. Insects were taken frequently.

Conclusions.—1. Preroosting activity in Redwing Blackbirds is initiated and terminated by variations in intensity of light from the overhead sky.

2. Evidence for the influence of light intensity and quality upon the rate of over-all activity is inconclusive, due to the paucity of data. These effects should be subjects of further study.

3. There is probably a seasonal cycle of activity which interacts with social effects. Detailed studies of the activities of flocks and solitary birds extending through at least one year should yield more evidence on these points.

4. The effects of weather changes upon overt behavior cannot be determined by the methods used in this study. They should be investigated under controlled laboratory conditions.

A NEW SUBSPECIES OF *ACMAEODERA QUADRIVITTATA* HORN (COLEOPTERA: BUPRESTIDAE)

JOSEF N. KNULL
Department of Zoology and Entomology, The Ohio State University, Columbus 10

Acmaeodera quadrivittata cazieri n. subsp.

Male.—Short, rather robust; color shining dark brown with bronze luster, each elytron with an irregular yellow band extending from umbone to near apex. Head convex, with median carina on vertex; surface closely, coarsely punctate; antenna when laid along side extending nearly to middle coxae, serrate starting with fifth segment.

EXPLANATION OF FIGURE
Acmaeodera quadrivittata cazieri n. subsp. Line equals 1 mm.

Pronotum wider than long, wider than base of elytra, widest back of middle; anterior margin sinuate, median lobe prominent; basal margin truncate, sides broadly rounded in front to back of middle then more strongly rounded to base, side margins not visible from above, margins continuous; disk convex, a slight depression in middle at base, a deep depression each side at base near umbone; surface with transverse corrugated band across base, moderately densely coarsely punctured in middle, punctures becoming larger, more numerous and umbilicate toward sides.

Elytra wide as widest part of pronotum; sides subparallel to basal third, then strongly rounded to apices; side margin serrate in apical three-fourths; disk convex, unbone prominent, a broad median depression at base; surface with strial punctures large, nearly contiguous, interspaces convex toward side margin, finely uniseriately punctate, second lateral interspace starting at umbone wider than others anteriorly and raised, a rugose on apical third, each interspace punctured, with a short hair.

Beneath prosternum slightly retracted, front margin shallowly emarginate. Abdomen densely punctate, each puncture with a short hair, last ventral segment unmodified.

Length 6.7 mm; width 2.6 mm.

Female.—Usually larger in size and more rounded apically, antennae slightly shorter.

Holotype ♂ and allotype from Chiricahua Mountains, Cochise Co., Arizona, July 19, 1952, D. J. and J. N. Knull collectors. Paratypes from the same locality labeled Sept. 12, 1947; June 27, 1949; July 19, 26, Aug. 2, 1952; July 13 to 29, 1953; July 17, 27, 1957 and July 2 to

Aug. 16, 1959; Huachuca Mtns., Cochise Co., Arizona, July 16 to 21, 1937; September 9, 1938, and Aug. 12, 1950, all collected by D. J. and J. N. Knull.

Holotype, allotype and paratypes in collection of author, paratypes in collections of American Museum of Natural History and The Ohio State University.

Adults are frequently abundant on flowers of thistle and prickly poppy. They were observed lighting on white areas of oil and beer cans which had been discarded on the ground.

This subspecies varies in length from 4.4 mm to 7.8 mm. It differs from *A. quadrivittata quadrivittata* by usually being larger in size, more robust and having just one yellow vitta on each elytron, instead of two.

It is named for Dr. Mont A. Cazier, through whose efforts biologists have been abe to study at the Southwestern Research Station of American Museum of Natural History near Portal, Arizona. The author is one of those who has availed himself of this opportunity.

A NEW SPECIES OF *ELAPHIDION* FROM TEXAS (COLEOPTERA: CERAMBYCIDAE)

JOSEF N. KNULL
Department of Zoology and Entomology, The Ohio State University, Columbus 10

The following *Elaphidion* is sufficiently different from *E. mucronatum* (Say) to warrant a name.

Elaphidion linsleyi n. sp.

Male.—Form of *E. mucronatum*; ground color dark brown, clothed with irregular recumbent pubescence.

Head convex, coarsely punctured, making area appear rugose; antennae extending over three segments beyond apices of elytra, when laid along side, scape stout, ratio of lengths of segments 1 to 11, 5:.8:6:4.4:5.6:6.3:6.3:6.3:5.5:5.3:7, segments 3 to 6 inclusive with short spines on inside at apices, spine on third segment longest, segments 6 to 10 inclusive with a very small tooth on outside at apices, segments 3 to 11 inclusive flattened.

Pronotum wider than long, widest in middle, wider at base than at apex; anterior margin sinuate, median lobe prominent; sides constricted at apex, then divergent, rounded at middle, converging to constricted base; surface convex, with irregular median smooth area, three like areas each side, one back of front margin on side, another in front of middle and one at base; surface very coarsely, confluently punctured. Scutellum transverse, finely punctate.

Elytra at base wider than widest part of pronotum; sides rounded at base, then slightly converging, apical fifth broadly rounded to emarginate bispinose apices, outer spine longer than sutural one; surface finely, evenly punctured, punctures separated by more than their own diameters.

Beneath intercoxal process of prosternum abruptly declivous posteriorly. Abdomen finely sparsely punctate. Middle and hind femora with a broad tooth on inside at apices.

Length 13.8 mm; width 3.6 mm.

Female.—Differs from male by antennae extending part of one segment beyond apices of elytra.

Holotype ♂, allotype and paratypes labeled Davis Mountains, Jeff Davis Co., Texas, July 3, 1955. Other paratypes from same locality labeled July 11, 15, 1955, July 14, 1957; Chisos Mountains, Brewster Co., Tex., June 30, 1957, June 17, 1958, June 27, 1959; Hidalgo Co., Texas, Mar. 20, 1952. All material collected by D. J. and J. N. Knull.

Holotype, allotype and paratypes in collection of author. Paratypes in collection of The University of California and The Ohio State University.

This species resembles *E. mucronatum*, however the apical spines on inside of middle and hind femora are broad. On *E. mucronatum* they are acute.

I am pleased to name this species for Dr. E. G. Linsley who has contributed greatly to our knowledge of Cerambycidae. I am indebted to him for examination of material.

DEVELOPMENT OF THE POLLEN AND THE EMBRYO SAC IN *CAPSICUM FRUTESCENS* L. VAR. JAPANESE VARIEGATED ORNAMENTAL[1]

PATRICIA A. LENGEL

The College of Wooster, Wooster, Ohio

INTRODUCTION

There is great variability in the species of pepper, *Capsicum frutescens* L. The fruits range from the large sweet Bell variety to the small pungent type; the height of the plants varies from eight inches to four feet and there is also wide variation of the flower and fruit in both color and shape. Some varieties are cultivated for their edible fruits and others for their ornamental qualities. Not only is there variability within the species, but variability also occurs within a variety and *C. frutescens* var. Japanese Variegated Ornamental offers an opportunity to observe variation within such a variety.

C. frutescens var. Japanese Variegated Ornamental is about eight to ten inches in height and has variegated—white, purple, and green—leaves. This variegation appears quite early in the growth of the plant, sometimes in the first true leaves, but more often in the second and third leaves. The variegation increases in the later formed leaves until there are some which are predominantly white. This variegation is expressed in an irregular pattern not commonly duplicated. Patterns of variegation occur in flowers and fruits as well as in the leaves. The flowers are typically purple, but occasionally a variegated—white and purple—one is found. The immature fruit color is purple becoming red upon maturing, but sometimes there is an intermediate striping.

This plant is readily propagated by seed, the variegations appearing similar to those of the parent. Most variegated plants are chimeras resulting from a somatic mutation occurring on one of the two outer layers of embryonic tissue of a stem tip; and since most leaves are derived from one or both of these layers, the mutant tissue may appear variously distributed in the mature leaves. Variations of this type can be propagated only vegetatively. Carpels, on the other hand, develop from the corpus or innermost portion of the embryonic stem tip; so, a genetic change which occurs in the first or second layer of the stem tip cannot be transmitted through the carpels (Blaydes, 1953). Since the variegated leaf areas develop in the seedling stages of the pepper variety used in this study, it is apparent that the origin of the variegated state can be explained by assuming the presence of an unstable gene which controls the formation of chlorophyll. If such is the case, each albino area of a given leaf blade represents a group of mutant cells in which the gene was in such a state that it could no longer initiate the formation of green pigment. Each variegated pepper plant then represents an individual in which numerous somatic mutations have occurred, and this occurs as a constant characteristic of this particular variety. For this reason it was felt that this pepper variety could be useful in demonstrating somatic mutations to students dealing with genetics and evolution.

Cochran (1938) reported the development of the pollen and the embryo sac of the Bell or sweet pepper, *Capsicum frutescens* var. *grossus*. He observed that the embryo sac was monosporic. In monosporic development of the embryo sac, the megaspore mother cell divides meiotically and four uninucleate megaspores are formed, each separated by a cell wall. Three megaspores of the tetrad then

[1]From a thesis presented in partial fulfillment of the requirements for the degree Master of Science, The Ohio State University, 1954.

THE OHIO JOURNAL OF SCIENCE 60(1): 8, January, 1960.

disintegrate with the megaspore at the chalazal end surviving. The nucleus of this remaining megaspore divides forming two nuclei which give rise to the two-nucleate embryo sac. These nuclei undergo two divisions, resulting finally in the eight-nucleate embryo sac. Cochran also observed that in *C. frutescens* var. *grossus*, the division of the generative nucleus took place in the pollen tube.

C. frutescens var. Japanese Variegated Ornamental has the same diploid number of chromosomes, twelve pairs, as *C. frutescens* var. *grossus*. Since there is so much variation in the species, *C. frutescens*, and its varieties, I thought that it would be valuable to study the development of the pollen and embryo sac in the Japanese Variegated Ornamental.

MATERIALS AND METHODS

Capsicum frutescens var. Japanese Variegated Ornamental was used for the pollen and the embryo sac studies. Flower buds were killed and fixed in Nawaschin's solution consisting of equal parts of solution A (4 parts of commercial 40% formalin and 1 part water) and solution B (1 gm of chromic acid and 10 cm^3 of acetic acid in 90 cm^3 of water). The material was dehydrated, infiltrated with xylene and paraffin, then embedded in paraffin. Longitudinal sections of the buds were cut 12 μ in thickness, mounted serially and stained with Heidenhain's Iron Hematoxylin. All drawings were made with the aid of a camera lucida.

OBSERVATIONS

In the flower buds of *Capsicum frutescens* var. Japanese Variegated Ornamental, the microspore mother cells differentiate directly from subhypodermal cells of the anther (fig. 1). Following the first meiotic division, no cell walls form between the daughter nuclei (fig. 2, 3). During the second meiotic division, four cells are formed resulting in a tetrad of microspores (fig. 4, 5, 6) that separates with each microspore developing an exine (fig. 7, 8). Following an enlargement of the microspore, the nucleus divides and the two nuclei resulting are unlike (fig. 9, 10). The tube nucleus is spherical and the generative nucleus is crescent-shaped (fig. 10). At the time of dehiscence, each pollen grain contains two linear-shaped sperm nuclei and a larger spherical tube nucleus (fig. 11).

Coinciding with the differentiation of the pollen in the anthers is the development of the embryo sac. A single archesporial cell differentiates in the hypodermal layer of the anatropous ovule (fig. 12) and is distinguished from the other cells by its larger size and its greater affinity for stain. The integument differentiates from the base of the nucellus at the time that the archesporial cell develops without further cell division into the megaspore mother cell (fig. 12). The megaspore mother cell elongates until it is about three times as long as it is wide (fig. 13). The nucleus which is almost as large in diameter as the cell itself contains a deeply staining nucleolus.

After the integument is fully formed, the nucleus of the megaspore mother cell begins to undergo meiotic divisions (fig. 13, 14), the axis of the spindle of the metaphase of the first division being parallel to the long axis of the megaspore mother cell (fig. 15). Following cell wall formation, the resulting cells are called dyads (fig. 16, 17).

When both cells of the dyad divide, the spindles are at oblique angles to the long axes of the cells (fig. 18). Cell walls do not form between the two nuclei of each cell, so meiosis ends with the formation of two binucleated cells (fig. 19). The micropylar binucleated cell becomes disorganized and finally disintegrates leaving the chalazal binucleated cell to become the two-nucleate embryo sac (fig. 20). Maheswari (1950) described this type of megaspore and embryo sac development as bisporic.

The two-nucleate embryo sac increases in length, the nuclei move to opposite ends of the embryo sac and become separated by a large vacuolated region (fig. 21). The cytoplasm surrounding the nuclei is more dense than in any other portion of

the cell. At this point in development, the embryo sac increases in both length and diameter. The chalazal and micropylar nuclei of the two-nucleate embryo sac divide, the resulting four nuclei being smaller than the previous two and orienting at either end of the embryo sac (fig. 22). All four nuclei divide simultaneously, giving rise to eight nuclei, four at each end (fig. 23). One nucleus of each group of four migrates to the center, and at this time the cytoplasm around each of the six remaining nuclei organizes into a cytoplasmic membrane (fig. 24). Sometime before fertilization, the polar nuclei fuse forming the fusion nucleus and a mature embryo sac.

DISCUSSION

The results of the study of the pollen and embryo sac development in *Capsicum frutescens* var. Japanese Variegated Ornamental do not coincide with those of Cochran (1938) for *Capsicum frutescens* var. *grossus*. He found that *C. frutescens* var. *grossus* had a monosporic type development of the embryo sac, while I have found a bisporic type development in *C. frutescens* var. Japanese Ornamental. Such variations as to embryo sac type within a species have been reported for *Erythronium americanum* by Hague in 1950 and *Ulmus fulva*, *U. racemosa* and *U. glabra* by Walker in 1950 (Maheshwari, 1950).

Cochran also observed for *C. frutescens* var. *grossus* that the division of the generative nucleus took place in the pollen tube, and my results show that particular division having taken place in the pollen grain of *C. frutescens* var. Japanese Variegated Ornamental.

SUMMARY

1. *Capsicum frutescens* var. Japanese Variegated Ornamental is a plant with variegated—white, purple and green—leaves and occasional striped flowers and fruits.

2. Every individual of *C. frutescens* var. Japanese Variegated Ornamental is regularly propogated by seed. This is most unusual for variegated plants, because variegation is not usually transmitted by gametes.

EXPLANATION OF FIGURES IN PLATE I*

1. The microspore mother cell (Approx. ×350).
2. The first meiotic division of the microspore mother cell (Approx. ×890).
3. The daughter nuclei following the first meiotic division of the microspore mother cell (Approx. ×410).
4. The second meiotic division of the microspore mother cell (Approx. ×710).
5. The tetrad of microspores (Approx. ×830).
6. The tetrad of microspores separating (Approx. ×790).
7. The microspores after the exine developed (Approx. ×770).
8. The exine of the microspores (Approx. ×470).
9. The microspore before the nucelar division (Approx. ×770).
10. The binucleate pollen grain (Approx. ×770).
11. The trinucleate pollen grain (Approx. ×750).
12. The megaspore mother cell in the anatropus ovule (Approx. ×170).
13. Prophase of the first meiotic division of the megaspore mother cell (Approx. ×820).
14. Prometaphase of the first meiotic division of the megaspore mother cell (Approx. ×710).
15. Metaphase of the first meiotic division of the megaspore mother cell (Approx. ×810).
16. The dyad before cell walls form (Approx. ×810).
17. The dyad resulting from the first meiotic division of the megaspore mother cell (Approx. ×770).
18. The second meiotic division of the megaspore mother cell (Approx. ×770).
19. The two binucleated cells (Approx. ×860).
20. The micropylar binucleated cell disintegrating (Approx. ×810).
21. The two-nucleate embryo sac (Approx. ×410).

*All figures in Plate I are photomicrographs.

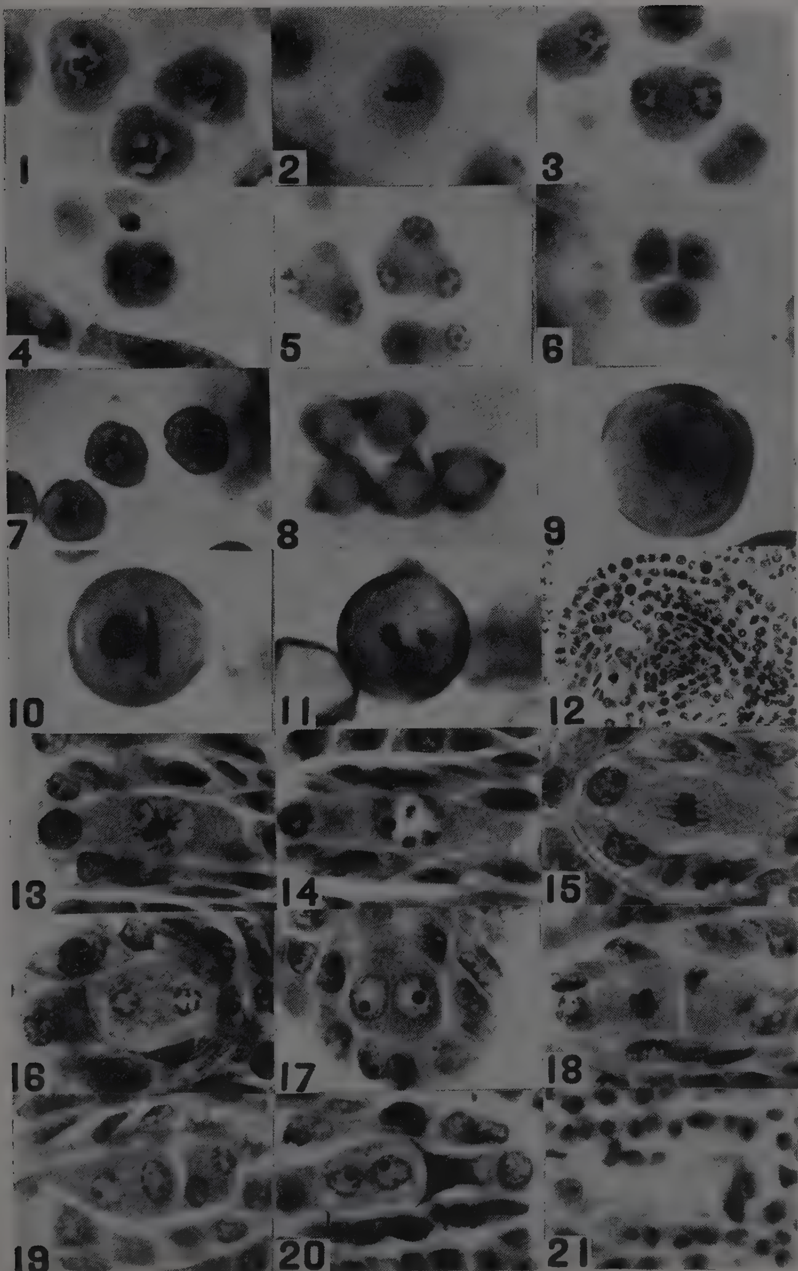


PLATE I

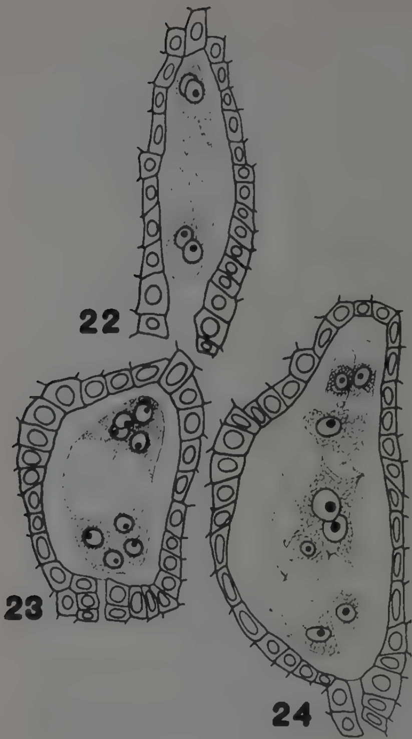


FIGURE 22. Four-nucleate embryo sac (Approx. × 300).

FIGURE 23. Eight-nucleate embryo sac (Approx. × 300).

FIGURE 24. Eight-nucleate embryo sac after the two polar nuclei migrate (Approx. × 300).

3. Each variegated area of a leaf may be explained by assuming that a somatic mutation occurred in a cell which becomes the forerunner of each albino area or patch of cells.

4. The chalazal binucleated cell becomes the two-nucleate embryo sac, hence the development is bisporic. This was not expected since the monosporic development had previously been described for the Bell pepper, another variety of the same species.

5. The generative nucleus divides before the pollen germinates, resulting in trinucleate pollen. This was unlike the development in the Bell pepper where the pollen is shed in the binucleate condition.

LITERATURE CITED

Blaydes, C. W. 1953. The romance of domesticated plants. Ohio Jour. Sci. 53: 93 215.

Cochran, H. L. 1938. A morphological study of flower and seed development in pepper. Jour. Ag. Res. 56: 395–419.

Maheshwari, P. 1950. An Introduction to the Embryology of the Angiosperms. McGraw-Hill Book Co., Inc., N. Y.

PLEISTOCENE MOLLUSCAN FAUNAS OF THE NEWELL LAKE DEPOSIT, LOGAN COUNTY, OHIO

JAMES A. ZIMMERMAN
Department of Geology, The Ohio State University, Columbus 10

INTRODUCTION

Nature and Purpose of Investigation

This report is primarily a paleoecological study of the molluscan fauna contained in the marl and peat deposits of Pleistocene Newell Lake. A detailed analysis of the fauna is made with special emphasis on the quantitative distribution of species to demonstrate changes in environment. It is hoped that this study, in conjunction with several others in progress, will prove useful in the establishment of faunal sequences which may be used in correlating Pleistocene nonmarine assemblages.

Location

The Newell Lake deposit is located in Union Township, Logan County, Ohio and lies in Section 11, Range 13, Township 4 (fig. 1) of the Between the Miamis district. The southeast corner of Section 11 is fixed at 40° 16' 34" North Latitude and 83° 48' 03" West Longitude. A buried kame field, composed of a complex of kames and associated gravel features, occupies an area of about thirty square miles southwest of Bellefontaine, Ohio. Till, varying in thickness from less than a foot to over 20 feet, covers the gravel (Forsyth, 1956, p. 137). It is in this buried kame field, between the Farmersville and West Liberty moraines, that the Newell Lake deposit is situated, six miles southwest of Bellefontaine and three miles northwest of West Liberty.

Access to the deposit may be gained by proceeding south from Bellefontaine on U. S. Route 68, a distance of 5 miles to Liberty Township Route 30, thence west two and one-quarter miles to a farm lane entering left onto the property of Mr. R. E. Starbuck. This lane proceeds south to the site of the present lake. Permission should be obtained before entering.

Methods of Investigation

In order to make quantitative determinations it was necessary to sample the Newell Lake deposit in successive two-inch layers throughout the vertical column. Several attempts were made before a station was located in which the rate of flow of ground water into the pit, as it was excavated, was sufficiently slow to maintain dryness by bailing. It was necessary to take three-inch samples in collections 20 through 24 because of the increased flow of ground water which finally terminated the sampling at that level. Sampling below collection 24 was accomplished through the use of a bayonet-type auger. These samples were utilized in the determination of the stratigraphy of the section below collection 24. Several other stations were sampled with the auger in order to outline the extent of the deposit and to establish several profiles.

Each sample at the chosen station measured 12 x 12 x 2 inches, except as noted above. The samples were placed in plastic bags, sealed, assigned a collection number and labeled. Samples in these bags maintain their moisture content indefinitely.

Due to the purity of the marl, soaking was not necessary prior to washing of the samples. The material from each collection was washed in a series of sieves from coarse to very fine. The residue was collected and placed on tables overnight to dry. This was collected when dry, placed in containers, and labeled.

The volume of the residue varied considerably (see fig. 2). In order to reduce the volume for study and to maintain a representative sample, each collection was separated into fractions by means of a Jones sample splitter. Different fractions were employed to facilitate sorting which were dependent upon the abundance of fossils in the particular collection (fig. 2). The total volume of each fraction was determined and portions of a fraction were ladled out at random,

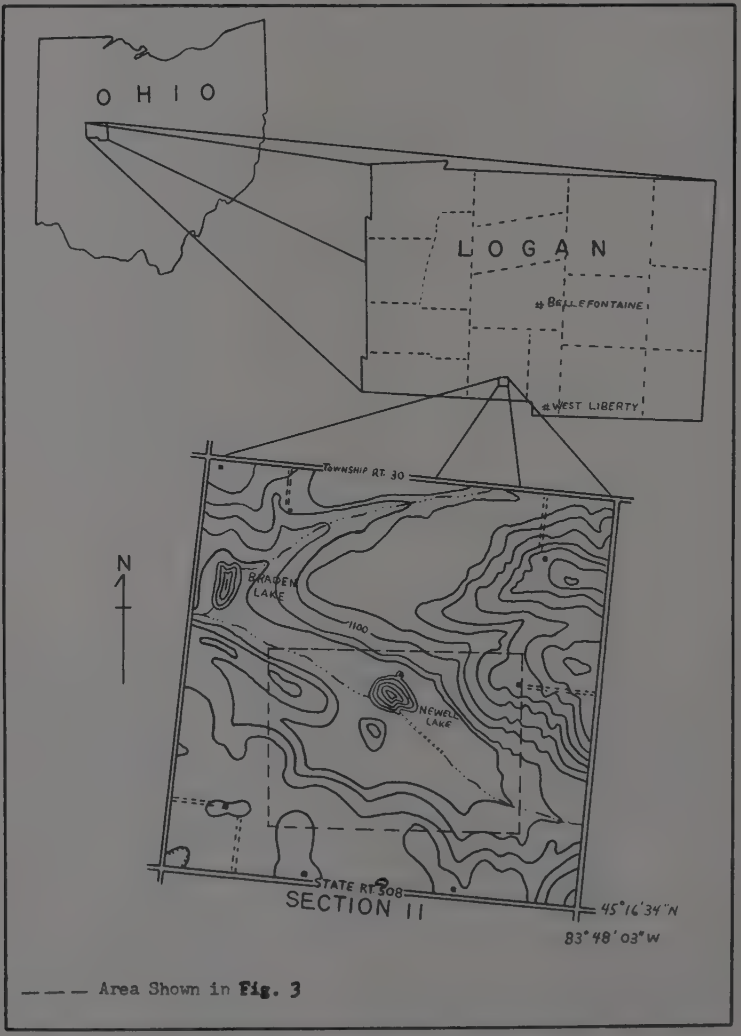


FIGURE 1. Index map showing the location of the Newell Lake area.

the volume also determined, and sorted until 1,000 shells were obtained. The volumes of the shells and of the residue were measured. From these data the total population of a given collection and the relative amount of vegetation (the residue consists primarily of shell fragments and vegetation) could be computed. The shells from each collection were later identified to genera and species. The percentage of each species was determined in each collection and also the volume of the total individuals in each collection (fig. 2). To evaluate the ecology, it is necessary to determine not only the specific assemblage but also the quantitative distribution of each species, the total volume of the population in each collection, and the relative amount of vegetation in each collection.

Coll. No.	Volume o. o. m.# in cc.	Volume of Mollusca in cc.	Total Mollusca
1	480	40	16,000
*2	704	1600	457,000
*3	704	2112	384,000
4	672	672	134,000
5	440	440	110,000
6	490	550	122,350
7	450	510	113,000
8	320	400	80,000
9	430	370	61,500
10	330	370	61,800
11	432	288	72,000
12	210	270	60,000
13	242	228	45,700
14	220	180	40,000
15	280	200	40,000
16	240	360	60,000
17	187	373	62,200
18	296	504	84,200
19	288	256	64,000
'20	180	300	60,000
'21	137	375	68,200
'22	107	213	53,300
'23	108	172	43,000

* Ratio of shell fragments to vegetation shows great excess over that of other collections.
' Collections are 3 inches thick; others are 2 inches thick.
\# o. o. m. - other organic material.

FIGURE 2. Vertical variation of Mollusca and other organic material in the Newell Lake deposit.

STRATIGRAPHY

Description of Deposit

Pleistocene Newell Lake lies at an elevation, determined along its perimeter, of 1077–1078 ft. It is 3000 ft long and averages 1200 ft in width, the longer axis extending northwest to southeast. On the west side, to the south of the outlet, there is a small esker (fig. 3) which is parallel to the long axis of the lake. A segment of this esker forms an island in the west central portion of the lake deposit. Bordering the center of the deposit, to the north and south, is a till covered outwash plain. Encompassing the southeast end of the deposit is a kame moraine. The lake deposits occupy a kettle hole amid the described surroundings.

Present day Newell Lake is situated at the northwest end of the deposit. It is at an elevation of 1075 ft. It measures 1000 ft in length, averages 500 ft in

width, and reaches a depth of 18 ft near its center. The marl has been quarried from the north-central margin of the lake forming an embayment. A drainage ditch has been dredged to the southeast for a distance of 1100 ft which serves as an inlet fed by an intermittent stream to the southeast. A second intermittent stream enters from a small ravine to the northeast. A small alluvial fan has been deposited over the marl where the ravine opens out into the valley. The lake formerly drained by overflowing to the northwest along a narrow channel which connects with Braden Lake (fig. 1). At present the channel is filled with

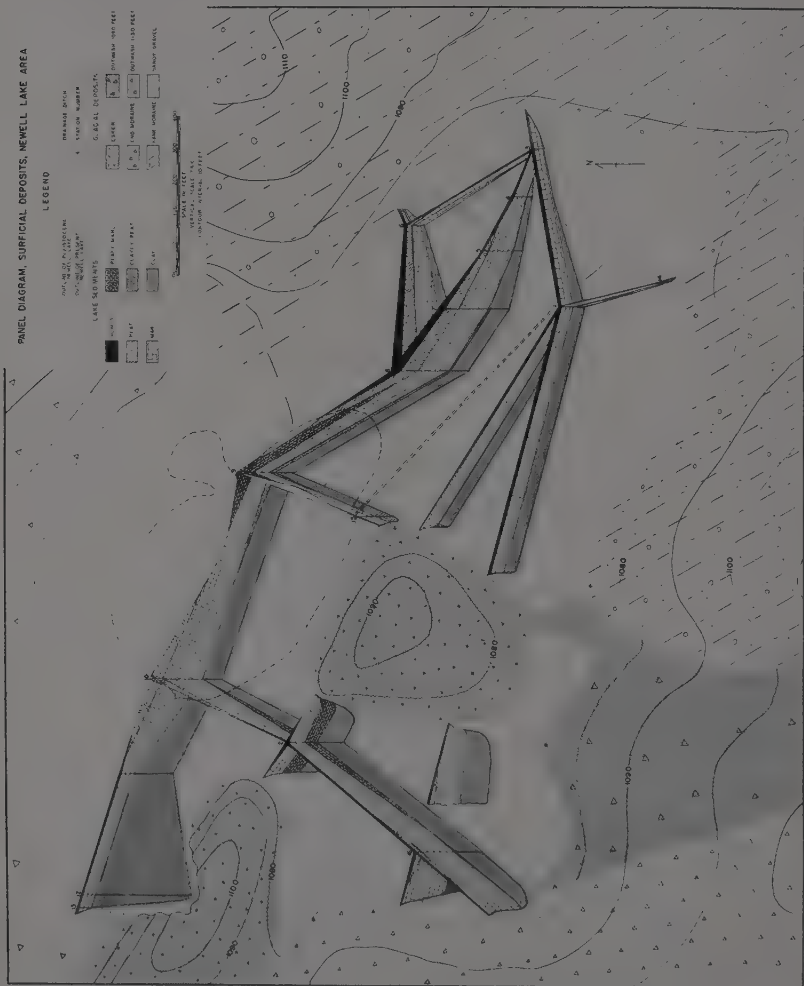


FIGURE 3. Panel diagram, surficial deposits, Newell Lake area.

sediment and drainage is accomplished by means of a tile drain set in the old channel. To the southwest of the present lake, at a distance of 1000 ft, is a swamp, the remnant of a shallow embayment of the once larger lake.

The marl ranges in thickness from a trace at the extreme margins to a maximum of 17 ft (see fig. 3). It is overlain throughout the deposit by a layer of brownish-black humus which averages 14 in. in thickness. Near the center of the main body of the deposit and near the center of the embayment to the southeast, a peat layer of varying thickness lies between the marl and the humus. At the same locations, a thin layer of peat 8 to 10 in. thick underlies the marl. Below the marl (or the peat layer as the case may be) is an olive gray clay which varies in thickness from a trace at the outer margins to a maximum of more than 40 ft. The clay rests throughout on a sandy gravel which could not be penetrated by the hand auger.

Both the overlying humus and the underlying olive gray clay are barren except in the southeast embayment area where the humus is fossiliferous. The marl is essentially pure (containing varying amounts of vegetation), pale yellowish brown, and highly fossiliferous. It changes in color downward to a light olive gray and the amount of vegetation and shells also decreases downward. There is a distinct break between the underlying clay, which is barren, and the overlying marl.

Measured Sections

These data for each section were obtained from the study of each core that was collected by means of the hand auger with the exception of Section 1 (see fig. 3 for location), which was collected from a hand excavated pit at two-in. intervals to a depth of 48 in., three-in. intervals from 48 to 60 in. Below the 60-in. level the remainder of the column was collected by means of the hand auger.

Colors and their corresponding designations were determined from the National Research Council Rock Color Chart. In each case the colors are those of the wet material.

The location of each measured section is indicated on figure 3 by a number at the top of each section.

Section No. 1

Unit	Description	Depth (inches)
1	Humus, compact, porous, noncalcareous, olive black (5Y 2/1), barren	0– 10
2	Humus, compact porous, noncalcareous, brownish black (5YR 2/1), fossiliferous inches 11–12. (Collection 1)	10– 12
3	Marl, fine, porous, moderately coherent, dark yellowish brown (10YR 4/2. Collection 2 and upper half of 3)	12– 15
4	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2), increase in vegetation at inches 34–38. (Collections 3 through 23)	15– 51
5	Marl, very fine, compact, light olive gray (5Y 5/2) becoming firm and clayey near the bottom	51– 72
6	Clay, tight, plastic, olive gray (5Y 4/1), barren	72–132
7	Sand, coarse, and gravel	132–

Section No. 2

Unit	Description	Depth (inches)
1	Humus, compact, porous, noncalcareous, olive black (5Y 2/1), fossiliferous	0– 14
2	Marl, fine, porous, moderately coherent, pale yellowish brown (10YR 6/2)	14– 90
3	Marl, peaty, fine, porous, becoming compact near the bottom, dark yellowish brown (10YR 4/2) above, moderate brown (5YR 3/4) below	90–158
4	Clay, tight, plastic, olive gray (5Y 4/1), barren	158–290
5	Gravel, sandy	290–

Section No. 3

Unit	Description	Depth (inches)
1	Silt loam, loose, crumbly, yellowish brown (10YR 5/6)	0– 10
2	Marl, sandy, loose, somewhat friable, pale yellowish brown (10YR 6/2)	10– 61
3	Gravel, sandy	61–

Section No. 4

Unit	Description	Depth (inches)
1	Humus, compact, porous, noncalcareous, olive black (5Y 2/1), barren	0– 11
2	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2)	11– 73
3	Clay, tight, plastic, olive gray (5Y 4/1), barren	73–116
4	Sand, coarse, and gravel	116–

Section No. 5

Unit	Description	Depth (inches)
1	Humus, compact, porous, noncalcareous, olive black (5Y 2/1), barren	0– 10
2	Peat, compact, blocky, olive black (5Y 2/1), becomes loose, porous, brownish black (5YR 2/1) toward the bottom	10– 36
3	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2)	36–160
4	Clay, tight, plastic, olive gray (5Y 4/1), barren	160–207
5	Sand, coarse, and gravel	207–

Section No. 6

Unit	Description	Depth (inches)
1	Humus, compact, porous, noncalcareous, olive black (5Y 2/1), barren	0– 12
2	Peat, compact, blocky, olive black (5Y 2/1), becomes loose, porous, brownish black (5YR 2/1) toward the bottom	12– 34
3	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2)	34– 90
4	Clay, tight, plastic, olive gray (5Y 4/1), barren	90– 97
5	Gravel, sandy	97–

Section No. 7

Unit	Description	Depth (inches)
1	Humus, compact, porous, noncalcareous, olive black (5Y 2/1), barren	0– 34
2	Peat, compact, blocky, olive black (5Y 2/1), becomes loose, porous, brownish black (5YR 2/1) at the bottom	34– 97
3	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2)	97–253
4	Peat, clayey, compact, leathery, moderate brown (5YR 3/4)	253–259
5	Clay, tight, plastic, olive gray (5Y 4/1). barren	259–359
6	Gravel, sandy	359–

Section No. 8

Unit	Description	Depth (inches)
1	Humus, compact, porous, noncalcareous, olive black (5Y 2/1), barren	0– 48
2	Peat, compact, blocky, olive black (5Y 2/1), becomes loose, porous, brownish black (5YR 2/1) at the bottom	48–132
3	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2)	132–288
4	Peat, clayey, compact. leathery, moderate brown (5YR 3/4)	288–296
5	Clay, tight, plastic, olive gray (5Y 4/1), barren	296–384
6	Gravel, sandy	384–

Section No. 9

Unit	Description	Depth (inches)
1	Peat, marly, loose, porous, dark yellowish brown (10YR 4/2)	0– 80
2	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2)	80–240
3	Peat, clayey, compact, leathery, moderate brown (5YR 3/4)	240–270
4	Clay, tight, plastic, olive gray (5Y 4/1), barren	270–366
5	Gravel, sandy	366–

Section No. 10

Unit	Description	Depth (inches)
1	Peat, compact, blocky, olive black (5Y 2/1), becomes loose, porous, brownish black (5YR 2/1) at the bottom	0–62
2	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2)	62–264
3	Clay, tight, plastic, olive gray (5Y 4/1), barren	264–360
4	Gravel, sandy	360–

Section No. 11

Unit	Description	Depth (inches)
1	Humus, compact, crumbly, olive black (5Y 2/1), barren	0–14
2	Marl, fine, loose, porous, pale yellowish brown (10YR 6/2)	14–78
3	Clay, tight, plastic, olive gray (5Y 4/1), barren	78–276
4	Gravel, sandy	276–

Section No. 12

Unit	Description	Depth (inches)
1	Humus, compact, crumbly, olive black (5Y 2/1), barren	0–8
2	Marl, fine, loose, porous, pale yellowish brown (10YR 6/2)	8–74
3	Clay, tight, plastic, light olive gray (5Y 5/2) above, olive gray (5Y 4/1), barren	74–554

Section No. 13

Unit	Description	Depth (inches)
1	Humus, compact, crumbly, olive black (5Y 2/1), barren	0–11
2	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2)	11–71
3	Clay, tight, plastic, olive gray (5Y 4/1), barren	71–95
4	Sand, coarse	95–

Section No. 14

Unit	Description	Depth (inches)
1	Humus, compact, porous, noncalcareous, olive black (5Y 2/1), barren	0–24
2	Marl, fine, porous, slightly coherent, pale yellowish brown (10YR 6/2)	24–36
3	Clay, tight, plastic, olive gray (5Y 4/1), barren	36–40
4	Sand, coarse, and gravel	40–

Section No. 15

Unit	Description	Depth (inches)
1	Humus, compact, porous, olive black (5Y 2/1), barren	0–14
2	Marl, fine, porous, coherent, pale yellowish brown (10YR 6/2)	14–92
3	Clay, tight, plastic, olive gray (5Y 4/1), barren	92–138
4	Gravel, sandy	138–

Section No. 16

Unit	Description	Depth (inches)
1	Humus, compact, porous, olive black (5Y 2/1), fossiliferous	0–14
2	Peat, loose, porous, brownish black (5YR 2/1)	14–24
3	Marl, fine, coherent, pale yellowish brown (10YR 6/2) becoming light olive gray (5Y 5/2) near the bottom	24–192
4	Peat, compact, leathery, moderate brown (5YR 3/4)	192–204
5	Clay, tight, plastic, olive gray (5Y 4/1), barren	204–342
6	Gravel, sandy	342–

QUANTITATIVE DISTRIBUTION

The Mollusca of the Newell Lake deposit are quite variably distributed. This distribution and its application to the interpretation of the paleoecology are important, especially when it is seen that there is basically very little change in the lithology of the fossil-bearing unit. For example, if one considers *Fossaria*

obrussa decampi, it is seen that this species is present in each of the 23 collections. This much information may be interpreted to mean that the environmental conditions were of a nature suitable for the existence of this species throughout the section. However, the quantitative data show that the species was exceedingly limited in collection 23 upward to collection 11 and most likely was an intruder at that particular station. From collection 11 upward it is apparent that the conditions became much more favorable for it to thrive and it becomes indigenous.

This section will be devoted to the discussion of the quantitative distribution of each species. Interpretations will be made later under the discussion of the paleoecology.

A total of 38 species were collected from the Newell Lake deposit, of which 26 were recovered from the collections at Station 1, where quantitative data were obtained for every species represented with the exception of *Valvata sincera* which was recovered below the collections by means of the auger. Of the 26 species, the maximum number represented in any one collection is 21 and the minimum is 12. Ten species occur in every collection with one additional species persistent from collection 19 upward. The two species of Naiades are represented for the most part by fragments and quantitative data for these are, therefore, very limited.

A minimum of 15 species (including the Naiades) occurs from collection 11 upward.

List of Species Represented in the Newell Lake Deposit

Pelecypoda

**Anodonta marginata* Say
**Lampsilis siliquoidea* (Barnes)
**Sphaerium lacustre* (Müller)
**Sphaerium sulcatum* (Lamarck)
**Pisidium casertanum* (Poli)
**Pisidium compressum* Prime
**Pisidium ferrugineum* Prime
**Pisidium nitidum nitidum* Jenyns
**Pisidium nitidum pauperculum* (Sterki)
**Pisidium obtusale rotundatum* (Prime)

Freshwater Gastropoda

Valvata lewisi Currier
**Valvata sincera* (Say)
**Valvata tricarinata* (Say)
**Amnicola leightoni* F. C. Baker
**Amnicola lustrica* Pilsbry
Pomatiopsis cincinnatiensis (Lea)
**Lymnaea stagnalis jugularis* Say
Stagnicola umbrosa (Say)
**Acella haldemani* ('Deshayes' Binney)
**Pseudosuccinea columella* (Say)
**Fossaria obrussa obrussa* (Say)
**Fossaria obrussa decampi* (Streng)
**Helisoma anceps striatum* (F. C. Baker)
**Helisoma campanulatum* (Say)
Helisoma trivolvis (Say)
Planorbula armigera (Say)
**Promenetus exacuous* (Say)
**Gyraulus altissimus* (F. C. Baker)
**Ferrissia parallela* (Haldeman)
Physa gyrina Say
**Physa sayii* Tappan

Terrestrial Gastropoda

Stenotrema monodon (Rackett)
**Hawaiia minuscula* (Binney)
Succinea ovalis Say
Oxyloma retusa (Lea)
Gastrocopta pentodon Say
Vertigo ovata (Say)
Vallonia pulchella (Müller)

*Species collected at Station 1.

The most significant species as to abundance are *Amnicola leightoni*, *Amnicola lustrica*, *Gyraulus altissimus*, and *Valvata tricarinata*. These four species comprise a minimum of 70 percent of the total individuals in each collection with the exception of collections 4 through 8 where their total decreases to 53 percent in collection 8. *V. tricarinata* (fig. 6) represents the greatest single occurrence by a species, comprising 51.5 percent of the total individuals in collection 23; it shows a gradual decrease upward to a minimum of 10 percent in collection 3. In comparison *G. altissimus* shows a gradual increase upward (fig. 14) to a maximum of 26.9 percent in collection 3. *Amnicola leightoni* and *A. lustrica* exhibit an overall decreasing trend upward (figs. 7 and 8) to collection 8, and then an overall increase upward from collection 7.

As discussed previously, *Fossarria obrussa decampi* is very limited in occurrence upward to collection 11. From collection 11 it shows a steady increase to a maximum of 21.5 percent in collection 7, followed by a steady decrease upward.

Six species are represented in several collections at least by more than one percent, but less than ten percent of the total individuals. Five of these: *Helisoma anceps striatum*, *Physa sayii*, *Promenetus exacuous*, *Pisidium ferrugineum*, and *Pisidium nitidum* are sufficiently abundant to be considered indigenous. Both *H. anceps striatum* and *Physa sayii* are present in all collections and show a relatively uniform distribution although *P. sayii* is somewhat more irregular in its distribution than *H. anceps striatum* (fig. 15 and 11). *Pisidium ferrugineum* and *P. nitidum* (fig. 4 and 5) exhibit erratic distribution. Both are exceedingly scarce in the lower collections but increase upward and become more numerous in collections 13 to 7. From collection 7 upward *P. ferrugineum* declines rapidly, whereas *P. nitidum* shows a decrease and then a sudden increase. *Promenetus exacuous* is present in all collections with the exception of 20 through 22. It shows a steady increase upward (fig. 13) from collection 18 to its maximum of 4.85 percent in collection 15; thereafter it shows a general decrease to a minimum of 0.1 percent in collection 2. The sixth species, *Helisoma campanulatum*, is present in all collections and is fairly uniform in its distribution (fig. 12); however, it is very limited in numbers and must be considered a marginal intruder, i.e. one whose habitat was not too far away from Station 1.

The remaining species at Station 1 are present in numbers that total less than one percent. All may be considered intruders with the exception of *Acella haldemani* (see p. 26).

The distributions just discussed are based upon the percentage of a species relative to the other species in a given collection. The true representation of the species must also include a consideration of the total number of that species in each collection. The total number is obtained by multiplying the total population of a given collection by the percentage, in that collection, of the species in question. For example, if we compare *V. tricarinata* in collections 23 through 21, it is seen, from figure 6, that there is a distinct decrease in percentage. By computing the total number of individuals in these collections, it is found that this species actually increased in absolute numbers.

PALEOECOLOGY

General Statement

The molluscan assemblage given on p. 20 is primarily a freshwater one and that of Station 1 is entirely freshwater. It is from these freshwater species and their relative abundance, that the environmental conditions and the changes in environment may be determined.

In order to understand the conclusions fully, data on the ecology are given for each species. In some cases the ecology must be inferred from related species or from other species that are considered synonymous. Vegetation, where given, refers to the shallow water communities which include the following: *Castalia*, *Chara*, *Dianthera*, *Lemna*, *Nymphaea*, *Pontederia*, *Potamogeton*, *Scirpus*, *Typha*, and *Vallisneria*. Data for pH and fixed carbon dioxide are quoted from Morrison (1932a). Food for the most part consists of diatoms, algae (commonly *Vaucheria*), other plankton, submerged vegetation, and bottom debris. The principal enemies are fish, and several of the species are infested by parasites.

Pelecypoda

Anodonta marginata *Say*.—This species is, for the most part, a mussel of lakes and is seldom found in rivers. It is found in shallow quiet lakes on mud bottoms, on exposed points, and in sheltered bays with sandy bouldery bottoms (Baker, 1918a, p. 166). It occurs in clear open waters, and among vegetation.

Morrison (1932a) observed that under extremely soft and acid water conditions, the shell developed is so thin that it may be twisted without cracking. It is impossible to twist the thicker shells developed under slightly alkaline conditions. Specimens taken from the lower peat layer of the Newell Lake deposit showed this pliable nature, whereas those taken from the marl were brittle.

Although the fragility of the species made it almost impossible to collect identifiable specimens, abundant fragments, two juvenile forms, and one identifiable adult were obtained from Station 1. Several additional specimens were collected from Station 2 a few of which were complete valves.

pH 6.03 to 8.37; fixed carbon dioxide 2.6 to 30.56 ppm.

Lampsilis siliquoidea (*Barnes*).—This species as stated by Ortmann (1919, p. 288) prefers rather quiet water and sandy-muddy bottoms. Strong currents and rough bottoms do not suit it although it is occasionally found in riffles. In such cases it has been washed out of the quieter pools. In the quiet water below riffles, where there is a more or less muddy bottom, or in slowly running water with fine gravel, sand and mud, it is abundant.

It occurs in lakes of all kinds, as well as in small and medium sized rivers; at depths of 0.2 m to greater than 30 m, more commonly from 1 to 2 m. It is generally found in clear water where vegetation is not abundant. All of the species of Lampsilinae, like the majority of species of the fresh water mussels, are limited to slightly alkaline water.

pH 6.9 to 8.14; fixed carbon dioxide 9.3 to 24.73 ppm.

Family Sphaeriidae.—The sphaeriids are quite variable and extremely difficult to identify to species. This situation has resulted, in many cases, in identification to genera only in the study of a particular fauna. The ecology of the species is therefore very limited. It is important to consider the ecology of the genera and supplement specific knowledge where it is available.

The sphaeriids live in all kinds of habitats. Many of them inhabit ponds or pools that dry up for a large part of the year. In these places, most of the animals die during the dry interval; a few survive by burrowing into the sand or deep into the mud bottom. The *Pisidia* often occur among vegetation. They occur in water of all depths. The adults bury themselves in the bottom but the young may be very active (Baker, 1928, p. 308). A great variety of bottom conditions are used; however, a firm bottom in which to burrow such as sand, mud, or clay, is preferred.

In the following discussion of the species, much of the ecology is drawn from one or more species, which are considered synonymous by Herrington (1954, p. 131–138) with the particular species under consideration. In each case the synonym is indicated.

Sphaerium lacustre (*Müller*).—This species inhabits shallow water among various bottom conditions from exposed gravel to fine deep mud. It prefers a firm bottom in water 0 to 0.6 m in depth. Baker (1928, p. 360) lists occurrences in the following environments: fine deep mud bottom, 0.6 m deep; hard clay bottom, 0.3 to 0.6 m deep; mud bottom, 0.5 m deep (*S. ryckholti*); pure hard packed sand (*S. jayense*). It has been recorded under swampy conditions among *Typha* and *Iris*.

pH 6.4 to 7.64; fixed carbon dioxide 9.3 to 18.87 ppm (*S. rosaceum*).

Sphaerium sulcatum (*Lamarck*).—This species belongs to eddies in streams and sometimes along the shores of lakes at a depth not much disturbed by wind action (van der Schalie, 1953, p. 85). It occurs on shallow bottoms of sand or gravel where there is a good current. Baker (1935) has collected it from the following environments: sandy silt or mud bottom, 1 m deep; sandy and rocky bottom with much debris. It is found among vegetation.

pH 6.9 to 8.37; fixed carbon dioxide 9.3 to 25.75 ppm.

Pisidium casertanum (*Poli*).—This species inhabits a sand or mud bottom, in shallow water, from 0.5 m to 3 m in depth. It occurs under swampy conditions or protected bays and has been collected by Baker (1916, 1918a, as *P. abditum*) from shallow water, with a sand, clay, or mud bottom, among vegetation. In Tomahawk Lake, Baker (1911a, *P. abditum*, *P. roperi*, and *P. subrotundatum*) records it from a swampy environment, among *Iris* and *Typha*. *P. abditum* was collected from soft sticky mud filled with algae.

pH 5.8 (*P. roperi*) to 7.95 (*P. strengi*); fixed carbon dioxide 5.5 (*P. roperi*) to 30.56 ppm (*P. strengi*).

Pisidium compressum *Prime.*—Baker (1928, p. 371) states "the typical form of *P. compressum* is confined principally to creeks and rivers." It is found on sandy, sandy silt, or mud bottom, in water 0 to 3 m deep among vegetation.

pH 7.0 to 8.37; fixed carbon dioxide 9.3 to 30.56 ppm.

Pisidium ferrugineum *Prime.*—Apparently an indigenous species in the upper collections of the Newell Lake deposit, *P. ferrugineum* inhabits mud, sand, or marly clay bottom in water 1 to 3 m deep, among vegetation, commonly *Vaucheria.*

pH 7.23 to 8.14; fixed carbon dioxide 10.8 to 12.5 ppm.

Coll. No.	No. of Individuals	Percent Total	Graphic Representation of Percent 2 4 6 8 10
1	1/2	0.06	
2	3/2	0.17	
3	1/2	0.05	
4	27/2	1.45	
5	23/2	1.38	
6	32/2	1.74	
7	93/2	5.32	
8	120/2	5.52	
9	99/2	5.40	
10	89/2	4.82	
11	59/2	3.10	
12	150/2	8.40	
13	74/2	3.99	
14	34/2	1.21	
15	16/2	0.82	
16	16/2	0.82	
17	20/2	1.02	
18	18/2	0.92	
19	54/2	2.79	
20	1/2	0.05	
21	1/2	0.05	
22	1/2	0.05	
23	2/2	0.10	

FIGURE 4. Quantitative distribution of *Pisidium ferrugineum* in the Newell Lake deposit.

Coll. No.	No. of Individuals	Percent Total	Graphic Representation of Percent 2 4 6 8 10
1	130/2	7.00	
2	107/2	5.66	
3	73/2	3.70	
4	79/2	4.24	
5	126/2	7.00	
6	124/2	6.76	
7	153/2	8.74	
8	128/2	6.02	
9	61/2	3.34	
10	61/2	3.30	
11	127/2	6.69	
12	101/2	5.52	
13	87/2	4.69	
14	35/2	1.76	
15	31/2	1.59	
16	33/2	1.69	
17	40/2	2.04	
18	23/2	1.27	
19	29/2	1.50	
20	13/2	0.66	
21	7/2	0.35	
22	7/2	0.35	
23	22/2	0.11	

FIGURE 5. Quantitative distribution of *Pisidium nitidum nitidum* in the Newell Lake deposit.

Pisidium nitidum *Jenyns.*—This species is the most abundant sphaeriid in the Newell Lake deposit. Like *P. ferrugineum* it is apparently indigenous in the upper collections. It inhabits shallow water 1 to 6 m deep, on sand, mud, or clay bottom, Baker (1928) lists the following occurrences: sand and mud bottom, 1.2 to 2.2 m (*P. minusculum*); mud bottom, 5.5 m, soft sand, shallow water (*P. splendidulum*); mud, 1.2 to 6.1 m, gravel 2.5 to 5.4 m, sand 0.3 to 0.8 m (*P. tenuissimum*).

pH 7.48 to 7.64 (*P. minusculum*); fixed carbon dioxide 12.96 to 18.87 ppm; pH 6.32 and fixed carbon dioxide 1.98 (*P. splendidulum*).

Pisidium nitidum pauperculum (*Sterki*).—This species is considered a distinct form of *P. nitidum* by Harrington (1954, p. 133). Its ecology may be considered essentially the same as *P. nitidum*. The following environments were noted by Baker (1928, p. 421): mud bottom, 1.5 to 1.7 m; mud bottom, 1.2 to 3.4 m; sandy mud bottoms 1 m; and a marly clay bottom, 10, 12.5, and 39.5 m (bleached shells).

pH 7.0 to 8.0; fixed carbon dioxide 9.3 to 24.73 ppm.

Pisidium obtusale rotundatum (*Prime*).—This species inhabits shallow ponds or lagoons, on mud or marly clay bottoms, in water that is shallow or moderately deep. The following environments are given by Baker (1928, p. 423–424): marly clay bottom, 9.5 to 11 m (*P. rotundatum*); mud bottom, 4.9 to 5.6 m; gravel bottom, 1.6 m; mud bottom, 9.5 m; sand bottom, 12 m (*P. vesiculare*).

pH 5.8 to 6.2; fixed carbon dioxide 1.97 to 9.0 ppm.

Freshwater Gastropoda

Valvata lewisi *Currier*.—This species inhabits ponds and lakes, especially the latter, living in water little more than one meter in depth, crawling on the mud or on aquatic vegetation (Leonard 1950, p. 11). It prefers shallow water with sand or silt bottom. Baker (1928, p. 28) notes that it is largely a lake species apparently not found in as deep water as *V. sincera*.

pH 7.35 to 7.7; fixed carbon dioxide 10.65 to 22.1 ppm.

Valvata sincera (*Say*).—Very little information is available on the ecology of this species. It is apparently a deep water form and occurs on gravel and mud bottoms. Baker (1916) did not list the species from Oneida Lake but further deep water dredging (1918a) produced *V. sincera*, which was most abundant in water 5 to 6 m deep. In Oneida Lake it seemed to be confined to water below 3 m. Robertson (1915) also recovered *V. sincera* from material dredged from a sandy bottom below 20 m. It seems to prefer coldwater lake habitats, with limited vegetation. It is recovered at present from the more northern lakes.

Coll. No.	No. of Individuals	Percent Total	10 20 30 40 50
1	262	28.3	
2	116	12.3	
3	98	10.0	
4	124	13.3	
5	166	18.4	
6	211	22.9	
7	148	16.9	
8	205	19.3	
9	245	26.8	
10	251	27.2	
11	256	27.0	
12	265	28.9	
13	305	32.9	
14	196	19.9	
15	220	22.6	
16	279	28.6	
17	301	30.6	
18	262	26.6	
19	285	29.4	
20	280	28.0	
21	353	35.3	
22	435	43.[illegible]	
23	500	51.5	

FIGURE 6. Quantitative distribution of *Valvata tricarinata* in the Newell Lake deposit.

Coll. No.	No. of Individuals	Percent Total	Graphic Representation of Percent 10 20 30 40 50
1	145	15.7	
2	165	17.5	
3	158	16.0	
4	119	12.8	
5	141	15.6	
6	109	11.9	
7	58	6.0	
8	68	6.5	
9	110	12.0	
10	124	13.4	
11	155	16.3	
12	106	11.6	
13	124	13.4	
14	225	22.6	
15	216	21.9	
16	165	16.9	
17	160	16.4	
18	185	18.8	
19	234	24.2	
20	190	19.1	
21	192	19.2	
22	179	17.[illegible]	
23	113	11.4	

FIGURE 7. Quantitative distribution of *Amnicola leightoni* in the Newell Lake deposit.

Beauchamp (1891, p. 52) states that *V. tricarinata* and *V. sincera* inhabit different haunts, eat different food, and if found together, it is in death rather than in life.

The Newell Lake specimens were recovered from auger samples taken in the section and at other sites. All were recovered from samples taken below eight feet.

The range of pH and fixed carbon dioxide may be inferred from its close relatives, *V. nylanderi* and *V. lewisi*. Morrison gives for *V. nylanderi* a pH of 7.6 and fixed carbon dioxide of 22.5 ppm (for *V. lewisi* see above).

Valvata tricarinata (*Say*).—Perhaps the most abundant of the fresh-water molluscs, this species is subject to considerable variation, especially in respect to carination. In discussing this form, the method proposed by La Rocque (1956) for designation of the variation is employed.

Valvata may be found under many varying conditions in streams and lakes. *V. tricarinata* is found from shallow water to depths exceeding 9 m. Baker (1928, p. 15) found that the strongly carinate form (111) is characteristic of rivers, whereas the variations 101 and 000 are confined chiefly to lakes. The relative distribution of these variations is shown in figure 16. It is evident from this figure, that the lake form 101, is most abundant throughout the section. *V. tricarinata* is the most dominant species in most of the collections, indicating that the environmental conditions must have been very favorable for it to flourish.

This species is abundant in weedy places on either sandy or muddy bottoms. None of the Valvatidae are found at a pH lower than 7.1 nor in water softer than that containing 8 ppm of fixed carbon dioxide. The ranges for *V. tricarinata* are: pH 7.16 to 8.37; fixed carbon dioxide 8.61 to 30.56 ppm.

Amnicola leightoni *F. C. Baker*.—This is an extinct species. It is necessary, therefore, to derive the ecology from *Amnicola limosa porata*, which is apparently the successor to *A. leightoni*.

A. limosa porata is the lake manifestation of *A. limosa*. It inhabits shallow water, ranging from swampy bays to sandy channels, but prefers protected muddy bays (Robertson, 1915). The following water depths and bottom conditions are listed by Baker (1928, p. 99–100): sand bottom, 0.3 m, vegetation; gravel, 0.3 m, vegetation; sand, 0.6 m, vegetation; boulder, 0.6 m, vegetation; gravel, 0.8 m vegetation; sandy silt, 0.9 m, vegetation; gravel in muck, 3.1 m. The

Coll. No.	No. of Individuals	Percent Total	Graphic Representation of Percent 10 20 30 40 50
1	147	15.9	
2	264	28.0	
3	271	27.4	
4	261	27.9	
5	162	18.0	
6	108	11.8	
7	119	13.6	
8	113	11.1	
9	127	13.9	
10	140	15.2	
11	150	15.8	
12	187	20.4	
13	186	20.1	
14	298	30.0	
15	230	23.7	
16	263	26.9	
17	257	26.3	
18	309	31.5	
19	223	23.1	
20	370	37.1	
21	280	28.0	
22	245	24.5	
23	226	22.8	

FIGURE 8. Quantitative distribution of *Amnicola lustrica* in the Newell Lake deposit.

Coll. No.	No. of Individuals	Percent Total	Graphic Representation of Percent 0.2 0.4 0.6 0.8 1.0
1	0	0.00	
2	trace	0.00	
3	0	0.00	
4	0	0.00	
5	0	0.00	
6	0	0.00	
7	1	0.11	
8	4	0.37	
9	3	0.33	
10	8	0.83	
11	10	1.19	
12	3	0.33	
13	9	0.97	
14	8	0.80	
15	1	0.10	
16	1	0.10	
17	0	0.00	
18	0	0.00	
19	0	0.00	
20	0	0.00	
21	0	0.00	
22	2	0.20	
23	1	0.10	

FIGURE 9. Quantitative distribution of *Acella haldemani* in the Newell Lake deposit.

presence of vegetation has been noted by Dennis (1928) as apparently the most important limiting factor in its environment. The depth of water and protection from exposure may be other limiting factors. Moffett (1943, p. 22) observed that *Amnicola* burrows beneath the sand during periods of storm. They are able to endure long periods without open water although moisture is necessary, but they may be virtually exterminated in their normal habitat by unusually high summer water temperatures.

Its ability to withstand the more extreme conditions of pH and fixed carbon dioxide content is undoubtedly a contributing factor to its range and abundance within a particular deposit.

pH 5.68 to 8.37; fixed carbon dioxide 1.2 to 30.56 ppm.

Amnicola lustrica *Pilsbry*.—This species is usually an inhabitant of vegetation and is particularly abundant in filamentous algae (Baker, 1928, p. 106). It occurs in shallow water, 0 to 2 m deep, on sandy-silt or mud bottom, rarely on gravelly or bouldery bottoms. It lives mostly in protected bays, where vegetation is abundant.

The following values are given by Morrison for the variety *A. lustrica decepta*: pH 6.85 to to 8.37; fixed carbon dioxide 9.3 to 30.56 ppm. It may be inferred that values for *A. lustrica* fall in the general range of *A. lustrica decepta*.

Pomatiopsis cincinnatiensis (*Lea*).—This species is found on wet earth and roots of trees along the margins of small streams. It is distinctly an amphibious snail. Although it seemingly prefers wet ground to actual immersion in water, it is perfectly at home when submerged. It

occurs in many places under leaves and on damp or wet mud in places more or less subject to overflow from streams and rivers. It is more tolerant of aquatic conditions than is *Succinea* (Berry 1943, p. 60). Leonard (1950, p. 13) notes that the snail is able to survive considerable periods of drought by closing the aperture tightly with the operculum.

Lymnaea stagnalis jugularis (*Say*) —Open swamps, or more or less stagnant parts of ponds or lakes, and rivers with abundant vegetation are the preferred habitats for this species. It may frequently be seen floating among pond-weeds and algae, or on floating logs. It lives on mud or sandy bottoms in shallow water, 0.5 to 1.5 m deep. A shore bordered with reeds and cattails is a favorite locality (Baker, 1911a). During periods of drought, *Lymnaea* will burrow into the sand or mud in an effort to survive.

Although it has primarily a diet of vegetation, as other molluscs, *L. stagnalis jugularis* has been seen to eat rotting vegetables and fruit, and is known to attack living animals, such as small fish.

pH 7.6 to 8.16; fixed carbon dioxide 15.8 to 23.0 ppm.

Stagnicola umbrosa (*Say*).—Baker (1928, p. 219) describes this species as an inhabitant of ponds and sloughs, which become more or less dry in the summer. It is abundant in pondlike areas where vegetation is thick. It is found on mud, silt, and clay at shallow depths of 0.3 to 1 m.

Much of the ecology of *S. umbrosa* may be inferred from *S. palustris elodes*, which is closely related. Baker (1928, p. 215) states ". . . (*S. palustris elodes*) is found plentifully in bodies of water of greater or less size, on floating sticks and submerged vegetation on stones and on the muddy bottom. Inhabits both clear and stagnant water, but prefers a habitat in which the water is not in motion. Seldom found out of the water. . . . The more distinctly malleated forms inhabit stagnant ponds where the bottom is muddy, with more or less decaying vegetation present. The food of *elodes* is made up of both animal and vegetable matter. . . ."

Morrison gives for *S. exilis*, a related species, these values: pH 5.9 to 7.74; fixed carbon dioxide 7.5 to 22.56 ppm. It may be inferred that *S. umbrosa* inhabits waters with similar but more restricted conditions.

Acella haldemani (*'Deshayes' Binney*).—The ecology of *A. haldemani* was for many years not completely understood. The fallacy that had done much to create a mystery in regard to *Acella* is the inference that it must migrate since only adult forms had been found. Dr. Reynold J. Kirtland (Baker, 1911b, p. 197) described it as a deep water species which migrates shoreward in the fall. In a more complete study of *Acella*, Morrison (1932b) recovered juvenile forms from the same places as the adults. He states that *Acella* does not migrate to deep water but remains in the zone of vegetation near shore at all times of the year and that when the vegetation has been killed down by winter conditions, the snags and logs serve as a substitute habitat on which to live and lay eggs. Studies of *Acella* in Ontario by Herrington (1947) revealed one colony in shallow water where there is no deep water for a half a mile; more conclusively, he found three juveniles in water 0 to 0.75 m in depth.

Baker (1928, p. 270) describes the species as an inhabitant of the larger lakes in more or less sheltered bays, always a protected habitat in water from 0.3 to over 1 m deep. In favorite habitat it forms colonies which cover several hundred yards, but the species is rarely found at any distance from the colony location. Dr. Kirtland noted that the location of the colony studied in Reed Lake near Grand Rapids, Michigan, did not vary a hundred feet in either direction over a ten year period. It is more sluggish in its movements than other Lymnaeidae. This slowness of motion will account, in part, for the colonial habits.

It dwells on a wide variety of vegetation, most commonly on the upper and lower sides of pond lily leaves and on floating or submerged vegetation. Variation in convexity of whorls and shape of the aperture shows that it has a correlation with the type of plant habitat. Narrow growth form, with flatsided whorls and proportionately narrower aperture, is produced when the individuals live on rushes, whereas a wider growth form, with slightly more convex whorls and a wider aperture is produced when *Acella* grows on other plants such as pond lilies burreed and pond-weed. (Morrison, 1932b).

A. haldemani is a sensitive and delicate species which occupies a rather restricted habitat of well-protected shallow water with abundant vegetation, along with a pH of 7.36 to 7.7 and a fixed carbon dioxide content of 17.0 to 22.56 ppm. Even in areas where the species thrives best

it is found in very limited numbers. The delicacy or fragility of the shell, its restricted habitat, the paucity of individuals even under optimum conditions, and its colonial nature, produce a poor record for the species, especially the fossil record.

Pseudosuccinea columella (*Say*).—This species is an inhabitant of ponds and streams, where the water is more or less stagnant. A locality with an abundance of lily pads is a particularly favorable habitat. It is found also along the shore in shallow water, in the midst of cattails and other reeds. It is rarely found in running water. *P. columella* occurs in shallow bays and small ponds or creeks, where it browses in the pond scum and on bits of rotting stems of water plants. Baker has collected this species associated with *Lymnaea stagnalis jugularis*, *Fossaria obrussa*, and *Stagnicola palustris elodes*.

Coll. No.	No. of Individuals	Percent Total	Graphic Representation of Percent 10 20 30 40 50
1	57	6.1	
2	53	5.6	
3	88	8.9	
4	95	10.4	
5	121	13.4	
6	154	16.8	
7	188	21.5	
8	138	13.0	
9	106	11.6	
10	50	5.4	
11	42	4.0	
12	5	0.5	
13	8	0.9	
14	4	0.4	
15	1	0.1	
16	2	0.2	
17	2	0.2	
18	14	1.4	
19	54	5.6	
20	8	0.8	
21	trace	0.0	
22	2	0.2	
23	14	1.4	

FIGURE 10. Quantitative distribution of *Fossaria obrussa decampi* in the Newell Lake deposit.

Coll. No.	No. of Individuals	Percent Total	Graphic Representation of Percent 2 4 6 8 10
1	12	1.20	
2	20	2.12	
3	11	1.11	
4	41	4.40	
5	25	2.77	
6	23	2.51	
7	19	2.17	
8	23	2.16	
9	39	4.26	
10	28	3.03	
11	38	3.47	
12	21	2.30	
13	16	1.73	
14	33	3.32	
15	36	3.70	
16	26	2.66	
17	25	2.56	
18	27	2.75	
19	26	2.90	
20	17	1.71	
21	11	1.11	
22	6	0.60	
23	18	1.82	

FIGURE 11. Quantitative distribution of *Helisoma anceps striatum* in the Newell Lake deposit.

Fossaria obrussa obrussa (*Say*).—The normal habitat of this species is in small bodies of water, such as creeks, ponds, sloughs, bays, and marshy spots along river banks. It is at home on sticks, stones, and any other debris that may be in the water or along its edge (Baker, 1928, p. 293). It occurs in shallow water, 0 to 1 m deep, with soft mud bottoms or where there is accumulated vegetable debris, frequently in or on the border of swamps where the water is very quiet. Baker (1911b, p. 281) notes that it frequently inhabits quarries which are abandoned and filled with water.

pH 5.86 to 8.37; fixed carbon dioxide 1.26 to 25.75 ppm.

Fossaria obrussa decampi (*Streng*).—This species is very abundant as a Pleistocene fossil and no doubt lived with *Fossaria galbana*, an extinct species. *F. obrussa decampi* is rarer in the recent fauna, possibly another species approaching extinction (Baker, 1928, p. 301). This species is a form of small lakes. The ecology of this species is probably the same as that of *F. obrussa* and may be assumed to have the same diet and natural enemies. Baker (1935, p. 264) recovered *F. obrussa decampi* living on a sandy-silt bottom, in water two ft deep, among *Scirpus* and *Chara*.

For the genus *Fossaria*, Morrison (1932a) notes that the common species *F. obrussa* is found from pH 5.9 to 8.3 while the supposed ancestral form *F. obrussa decampi* is found under much more restricted conditions; which immediately raises the question as to which is the ancestral form and which is the special form found under a special set of conditions attendant upon recently formed glacial lakes.

pH 7.42 to 7.7; fixed carbon dioxide 10.65 to 18.87 ppm.

Helisoma anceps striatum (*F. C. Baker*).—Once considered extinct but now known from the more northern lakes, *H. anceps striatum* is usually found in shallow water among vegetation growing on a mud or clay bottom. It is similar to *H. anceps anceps* in its habitat and inferences may be made, to some extent, where the record is lacking. Baker's account (1935) of North Star Lake, Minnesota, lists *H. anceps striatum* in habitats generally 1 m deep, with sand or sandy silt to mud bottom, more or less protected, and with abundant vegetation.

This species is apparently indigenous in the section examined. Its distribution in the Newell Lake deposit closely parallels that of *Physa sayii*, both in total individuals and in comparative numbers of adult and juvenile forms.

pH 6.08 to 8.02; fixed carbon dioxide 2.66 to 30.56 ppm.

Coll. No.	No. of Individuals	Percent Total	Graphic Representation of Percent 2 4 6 8 10
1	trace	0.00	
2	2	0.21	
3	16	1.62	
4	1	0.11	
5	2	0.22	
6	7	0.76	
7	trace	0.00	
8	1	[illegible]	
9	6	0.66	
10	9	0.97	
11	7	0.74	
12	20	2.19	
13	6	[illegible]	
14	5	0.50	
15	13	1.34	
16	15	1.54	
17	11	1.1[illegible]	
18	15	1.53	
19	3	0.31	
20	3	0.30	
21	2	0.20	
22	2	0.20	
23	2	0.22	

FIGURE 12. Quantitative distribution of *Helisoma campanulatum* in the Newell Lake deposit.

Coll. No.	No. of Individuals	Percent Total	Graphic Representation of Percent 2 4 6 8 10
1	3	0.32	
2	1	0.10	
3	2	0.20	
4	10	1.10	
5	10	1.10	
6	4	0.40	
7	1	0.11	
8	5	0.45	
9	5	0.54	
10	20	2.16	
11	26	2.73	
12	11	1.18	
13	20	2.15	
14	46	4.60	
15	47	4.85	
16	29	2.15	
17	29	2.95	
18	10	1.00	
19	3	0.30	
20	0	0.00	
21	0	0.00	
22	0	0.00	
23	4	0.40	

FIGURE 13. Quantitative distribution of *Promenetus exacuous* in the Newell Lake deposit.

Helisoma campanulatum (*Say*).—This species occurs in shallow water, exposed or protected, on a great variety of substrata, from bare rock bottom to deep mud. Robertson (1915, p. 100) found it in weedy places, both sandy and muddy, up to 6 m in depth. He describes it as not fitted for exposed situations because of the size and shape of its shell and the vertical position in which it is carried. Baker (1911b, p. 236), on the contrary, states that it apparently prefers a habitat where wave action is marked, on sandy or pebbly shores. From collections made by Baker (1916, 1935), *H. campanulatum* occupies the same habitats as *H. anceps striatum*, but in addition was found on boulder and pebble bottoms along exposed shores.

pH 6.6 to 8.16; fixed carbon dioxide 7.5 to 30.56 ppm.

Helisoma trivolvis (*Say*).—This species, according to Baker (1928, p. 332-333), is always an inhabitant of quiet, more or less stagnant water. It occurs along swampy shores, in marshes, or in stagnant pools, with mud or fine sandy-silt bottoms, up to 2 m in depth although generally in water less than 0.6 m deep. Robertson (1915) reports that it prefers shallow bays with comparatively high temperature.

It may be found on the under sides of lily leaves, on driftwood, or among dead vegetation. Leonard (1950) states that it is invariably absent from flowing streams and that its presence in an assemblage of fossils is a good indicator of the presence of ponded water, since the species is so restricted in its habitat.

pH 6.6 to 8.37; fixed carbon dioxide 7.5 to 30.56 ppm.

Planorbula armigera (*Say*).—This species is largely one of swales or of small and stagnant

bodies of water (Baker 1928, p. 358). It prefers the quiet waters of small lakes or ponds where there is abundant vegetation and a mud or silt bottom 0 to 1 m in depth.

It is fairly active in woodland pools at the edges of marshes and in ditches and small streams. It is apparently capable of lying dormant in drier mud during the greater part of the year (Goodrich 1932, p. 67).

pH 6.6 to 7.6; fixed carbon dioxide 7.5 to 16.7 ppm.

Promenetus exacuous (*Say*).—This species is an inhabitant of quiet places on all varieties of bottom from 0.5 m to 5 m deep. It is most abundant on sand and mud bottoms in 0.6 m to 1.6 m of water. It is rare on a gravel bottom but may be common on a boulder bottom. It is listed by Baker (1928, p. 362–363) from soft, silty bottoms to sticky mud or on logs.

From studies made in the Bass Island Region, Lake Erie, Dennis (1928) concluded that temperature is apparently the most important factor in the distribution of *Promenetus* since it was found at only one station in water at 17° C which was lower than any of the other stations by 4° C. Vegetation is undoubtedly another important factor in its distribution. The presence of abundant vegetation would tend to lower the temperature on account of the shade afforded.

It commonly occurs in protected weedy places on driftwood, lily pads, and on dead leaves. Baker (1916) found it in shallow water, 0.5 m to 1 m deep, on a muddy bottom with accumulation of dead plant debris where it was common on dead *Typha* leaves.

pH 7.0 to 7.64; fixed carbon dioxide 9.3 to 22.5 ppm.

Gyraulus altissimus (*F. C. Baker*).—Since the species is considered extinct (Baker lists it as living in southern Saskatchewan; see Russell 1934), no precise ecological data can be given except by inference from its related forms. La Rocque (1952, p. 15) drew inferences from its close relative *G. arcticus*. Morrison (1932a) showed that in the subgenus *Torquis* a marked series occurs consisting of *G. circumstriatus*, *G. parvus* and *G. arcticus*, in which a direct relationship of carination to acidity was revealed. A similar relationship was observed for *G. deflectus*, *G. obliquus*, and *G. hirsutus*, of the subgenus *Gyraulus sensu stricto*. From the examination of several representative faunas similar in composition to that of Newell Lake, it was observed that *G. parvus* occurred with *G. deflectus* or *G. obliquus*, and that *G. hirsutus* occurred with *G. arcticus*. It was also noted that, although no pH values were given, the stations from which *G. arcticus* were obtained showed environments that could be expected to be more alkaline. Comparison of faunas from several marl deposits revealed *G. altissimus* occurring most often with *G. deflectus*. The typical *G. altissimus* in the Newell Lake deposit shows development of carination, especially in the more adult forms. Since, as Baker (1928, p. 383) states, *G. altissimus* takes the place of *G. parvus* in most marl deposits, and based on consideration of the comparisons made above, *G. parvus* appears to be more closely associated with *G. altissimus* in regard to environment and distribution. The following ecology is, therefore, drawn from *G. parvus*.

G. altissimus most likely inhabited quiet bodies of water of small size, protected, with sandy silt, sandy mud, mud, or muck bottom; in water ranging from 0.5 m to 2.2 m in depth, and partial to a habitat which had rather thick vegetation. Dennis (1928) found that depth of water is apparently a limiting factor since it is always found in shallow water or on vegetation near the surface. It is always in protected places. The important limiting factors, therefore, are wave action and vegetation.

pH 7.0 to 8.16; fixed carbon dioxide 8.16 to 30.56 ppm.

Ferrissia parallela (*Haldeman*).—Baker (1928, p. 397) describes this species as an inhabitant of quiet water, on plants and the shells of Naiades, in shallow water, from 0.3 m to 2 m deep. It is commonly found near the water's edge. The animal occurs usually near the surface on the under-side of lily leaves, or on sticks. The presence of vegetation, as noted by Dennis (1928, p. 29), seems to be an important factor in the distribution of *F. parallela*. Lack of wave action is undoubtedly a factor, since they are found only in quiet, protected waters.

Johnson (1904) has described one method of distribution of the Ancylidae in which the animal attaches to the wing of water beetles and may become widely distributed.

pH 6.05 to 8.37; fixed carbon dioxide 2.75 to 25.75 ppm.

Physa gyrina *Say*.—This species appears to be characteristic of swamps and slow moving stagnant bodies of shallow water, usually on a mud bottom. It has been found in overflows from large rivers, in small ponds, behind river and lake beaches (Baker 1928, p. 451–452). It occurs on rock bottom, sand, sandy silt, and mud, in water 0.1 to 1 m deep, among vegetation.

pH 7.1 to 8.37; fixed carbon dioxide 9.5 to 25.75 ppm.

Physa sayii sayii (*Tappan*).—Although much detailed information is available concerning the genus *Physa*, very little is actually given for the exact ecology of *P. sayii*. From its close relation to *P. warreniana*, inferences as to its ecology may be made.

In general, still water offers much more favorable conditions for *Physa* than does flowing water. In the littoral zone, *Physa* is found even in unprotected places. Dawson (1911) lists the optimum environmental conditions as shallow water; minimum amount of shade; few or no enemies; minimum amount of debris; protection from waves or currents; moderate amount of water weeds and well-aerated water.

Decaying vegetation takes up oxygen and liberated carbonic acid. Under such conditions few *Physa* occur. If *Physa* is to inhabit lakes or ponds in any numbers it can do so only when, by some means or other, the growth of the pond weed is checked.

Coll. No.	No. of Individuals	Percent Total	10 20 30 40 50
1	212	22.9	
2	225	23.8	
3	266	26.9	
4	143	15.4	
5	161	17.8	
6	196	21.4	
7	203	23.2	
8	182	17.1	
9	168	18.4	
10	182	19.8	
11	137	14.4	
12	131	14.3	
13	146	15.7	
14	112	11.2	
15	107	11.0	
16	132	13.5	
17	122	12.4	
18	95	9.9	
19	85	8.8	
20	84	8.4	
21	126	12.6	
22	118	11.8	
23	92	9.3	

FIGURE 14. Quantitative distribution of *Gyraulus altissimus* in the Newell Lake deposit.

Coll. No.	No. of Individuals	Percent Total	[illegible]
1	13	1.40	
2	28	2.96	
3	28	2.84	
4	77	8.26	
5	33	3.66	
6	24	3.16	
7	13	1.48	
8	23	2.26	
9	[illegible]9	3.17	
10	29	3.14	
11	49	5.15	
12	55	6.00	
13	37	3.99	
14	40	4.02	
15	7[illegible]	7.54	
16	45	4.60	
17	48	4.[illegible]0	
18	44	4.47	
19	19	1.96	
20	35	3.21	
21	3[illegible]	3.00	
22	6	0.6[illegible]	
23	8	0.80	

FIGURE 15. Quantitative distribution of *Physa sayii* in the Newell Lake deposit.

The habitat of *P. warreniana* is near shore in shallow water, ranging from bouldery exposed points to protected bays filled with vegetation. Baker (1928, p. 432) lists the following conditions under which *P. sayii* has been found: rocky bottom, shallow water; sand with vegetation, 0.6 m deep; gravel, 0.8 m deep; sand bottom, 0.3 m deep; mud bottom, 3.7 to 5.5 m deep, boulder bottom, 0.5 m deep.

Unlike many *Physa*, which are more commonly river or stream inhabitants, living in or near moving water, *P. sayii* apparently prefers a shallow, more protected environment such as is provided by sheltered small lakes or by embayments in larger lakes. The species does thrive, however, along beaches and Clench (1925) has collected specimens from aquatic plants in water 20 to 25 ft deep.

pH 5.68 to 7.96; fixed carbon dioxide 1.2 to 22.5 ppm.

Terrestrial Gastropoda

Stenotrema monodon (*Rackett*).—This species is a woodland snail usually found in moist situations. It thrives best on leaves or near old stumps or logs among trees. Although not a colonial species, it is often numerous at a favorite site (Leonard and Goble 1952, p. 1039). Archer (1948, p. 57) states that it lives in marshes and wooded swamps along banks of streams, on river plains and shores of lakes and ravines adjacent to rivers. It is also present in tall grass prairies, in open fields. It may be found on low terraces and flood plains under leaves, logs and stones.

Hawaiia minuscula (*Binney*).—This species is an inhabitant of humid situations where it lies in leaf mold or beneath the bark of trees, among mosses and beneath fallen logs, or beneath stones. In spite of its habitat preferences, it is capable of withstanding long periods of drought and high temperatures. It prefers a woodland environment in loose moist soil under a light layer of decaying vegetation, under leaves, among grass roots and under decaying logs (Leonard 1950, p. 36).

Alive, it is to be found rarely in numbers greater than four or five individuals, normally by the borders of streams and lakes, but it is one of the commonest shells of stream drift (Goodrich 1932, p. 33).

Coll. No.	Variation					
	111	101	100	110	001	000
1	39	175	45	1	2	0
2	10	76	30	0	0	0
3	2	48	48	0	0	0
4	7	97	27	0	0	0
5	4	153	9	0	0	0
6	3	201	7	0	0	0
7	7	139	0	0	0	0
8	8	197	3	0	0	0
9	27	215	1	0	0	0
10	19	231	5	0	0	0
11	10	241	2	0	0	0
12	30	233	0	0	0	0
13	37	268	0	0	0	0
14	25	171	0	0	0	0
15	27	193	0	0	0	0
16	30	249	0	0	0	0
17	28	273	0	0	0	0
18	21	241	0	0	0	0
19	12	273	0	0	0	0
20	10	270	0	0	0	0
21	14	339	0	0	0	0
22	22	413	0	0	0	0
23	15	482	2	0	0	1

FIGURE 16. Variation in the carination of *Valvata tricarinata*.

Succinea ovalis *Say*.—This species is an inhabitant of moist situations near ponds, swamps, and streams, often among trees or shrubs. It is abundant along the flood plain of the Missouri River where it lives among the grasses and sedges on mud flats, but it often ascends the wooded bluffs where moisture is abundant. Its preference for the moist environments is so characteristic that its distribution on a wooded slope may be suddenly truncated above a horizon where contact springs emerge (Leonard 1950, p. 24).

Goodrich (1932, p. 39) states, "The snail prefers drier localities than those frequented by *O. retusa* and often is to be found among the weeds of the edges of upland pools. In wet seasons it has been seen ten or twelve feet above the ground upon the trunks of smooth-barked trees."

Oxyloma retusa (*Lea*).—This species occurs in marshes and other wet places. It can be found upon partly submerged sticks, on rotting water weeds and often high on the stems of cattails. Frequently, it is in the company of *Lymnaea* (Goodrich 1932, p. 38). It has been collected by Baker (1935) from grass covered shores a few feet above the water line on pieces of bark and wood, and from pond lily leaves in a community of *Nymphaea* and *Castalia*. It commonly occurs on mud flats above the high water level along swampy shores caused by the raising of the water level in a lake or pond.

Gastrocopta pentodon (*Say*).—This species inhabits moist places under logs and stones on

wooded slopes and poorly drained flood plains and among grass roots on open slopes. Leonard and Goble (1932, p. 1083) noted that it occurs abundantly on the drier west and south facing hillsides than on the north facing slopes. It is found on the forest floor among deep layers of leaf mold or under wet pieces of bark and on fallen trees.

Vertigo ovata (*Say*).—This species is also an inhabitant of moist places, being found among vegetation in swampy areas and along stream banks and other bodies of water. A limiting factor seems to be moisture (Leonard and Goble 1952, p. 1034).

Franzen and Leonard (1947, p. 355) state, "*Vertigo ovata* although found in various parts of the state (Kansas), lives only in moist environs afforded by shaded slopes near streams and shores of ponds. . . . In these regions are local ponds and streams, many of which are fed by artesian springs along whose shaded slopes *V. ovata* is found, though not in great numbers."

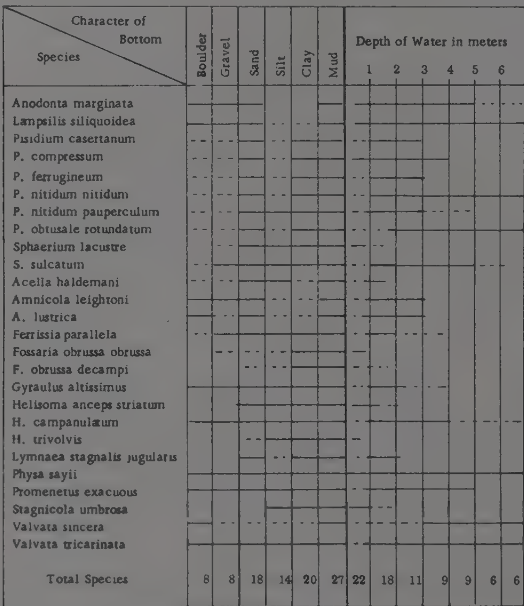


FIGURE 17. Relations of Mollusca to character of bottom and depth of water.

Vallonia pulchella (*Müller*).—This species lives under dead grass in crevices in stones, in moss under stones, boards, and dead wood, and after a rain, often appears in enormous numbers in localities where it has become established (Leonard 1950, p. 53). It has adapted itself to the environmental conditions established by the white man, and is probably now far greater in numbers than in the older heavily forested days. (Goodrich 1932, p. 10).

DISCUSSION

The molluscan assemblage of the collections at Station 1 is entirely fresh water with the exception of *Hawaiia minuscula*. The absence of a peat layer within the marl would indicate the presence of a permanent body of water throughout the period of deposition. This condition is confirmed by the average environmental conditions of the indigenous species.

Examination of figures 17 and 18 reveals the following are the optimum conditions for the fauna at Station 1. Bottom; mud, clay, or sand; water: 0.1 to 3 m deep, calm, clear; pH 7.6 and fixed carbon dioxide 13.0 ppm. Such an environment

obviously did not persist throughout the period of deposition, nor is it assumed that all of these conditions occurred together at any one time. It is highly likely, however, that these conditions did obtain during the greater part of the time of development of the deposit.

The above inferences may be drawn from the specific assemblage of the deposit alone. Analysis of the quantitative and volumetric data throughout the several collections and comparison with the specific assemblage of these separate collections reveals the more discrete details of the environmental history.

Figure 2 lists the volumetric data and the estimates of the total Mollusca in a 12 x 12 x 2 in. layer for each collection. Figure 19 illustrates the relationship of the volume of the Mollusca to the volume of the other organic material. It is seen from the graph that an overall direct relationship exists between the two. Since the total Mollusca are a function of the volume and the volume of shell fragments remains relatively uniform, with the exception of collections 3 and 2, comparisons illustrated in figure 19 may be considered to be between the molluscan population and the amount of vegetation in each collection. Beginning with collection 23 and proceeding upward, an analysis of the environment of Station 1 may be made.

Collections 23 through 18 show an overall increase in both the total population and the amount of vegetation. Such a trend is expected in accordance with the conclusions of Dawson (1911, p. 29): 1. Where the pond weeds have captured quiet waters, no snails, alive or dead were found. 2. Snails live in moderate numbers where there is luxurious growth of weeds, if there be a considerable depth of water above the plants or if the water is gently flowing over them. 3. The snails occur in the greater numbers where there is a moderate amount of water plants and organic debris.

If the water were gradually becoming more shallow, the vegetation would most likely increase at the site and the population would increase. That the water was becoming more shallow is indicated by the absence of *V. sincera*, a deep water species, which is present in the marl below collection 23, and by the increase of *G. altissimus*, *A. lustrica*, and *A. leightoni*. As discussed previously (p. 17) *V. tricarinata* shows a slight increase in total numbers.

Collections 17 through 14 exhibit a wide fluctuation in vegetation, accompanied by a relatively steady decrease in total population. *V. tricarinata* and *G. altissimus* show a decrease in the same collections, whereas other species, *P. exacuous*, *A. leightoni*, *H. anceps striatum*, and *A. haldemani* increase. The general changes noted in these collections suggest fluctuations in the water level and corresponding unstable environmental conditions with a trend towards a shallow, quiet, protected environment necessary for the existence of *Acella*.

An examination of collections 13 through 7 reveals an increase in both the amount of vegetation and the total population. *V. tricarinata* remains relatively unchanged and *G. altissimus* increases slightly. *F. obrussa decampi* increases greatly. *A. lustrica* and *A. leightoni* decrease in percentage, but increase in actual numbers. *P. nitidum* and *P. ferrugineum*, and the Naiades show an increase. *Ferrissia parallela* makes its only appearance in these collections. These changes reflect the increase in vegetation and suggest a continual trend toward shallower water, almost swampy conditions.

The most significant change throughout the deposit occurs in collection 11. There is a great increase in the amount of vegetation and a marked increase in the total population (see fig. 19). *Acella haldemani* attains its maximum numbers, and *F. obrussa decampi* exhibits a great increase in number. The Naiades are greatly increased and three additional species, *Pseudosuccinea columella*, *Lymnaea stagnalis jugularis*, and *Fossaria obrussa* appear.

These distinct changes, particularly in the specific assemblage, suggest a sudden

lowering of the water level causing the shoreline to migrate toward the Station sufficiently to allow the great increase in vegetation. The shoreline was, however, not close enough to allow choking of the waters which might affect other species. Also, the appearance of the additional species, their very limited numbers, and their disappearance in the very next collection suggests that the water probably did not remain at this low level for very long.

From collections 7 upward through collection 1 there is a great increase both in vegetation and in total population. At the same time there is a general decrease in the relative percentages of the less significant species, whereas *G. altissimus*, *A. leightoni*, and *A. lustrica* increase. *V. tricarinata* decreases slightly in percentage but shows little change in total numbers. *P. columella*, *L. stagnalis*, and *F. obrussa* reappear.

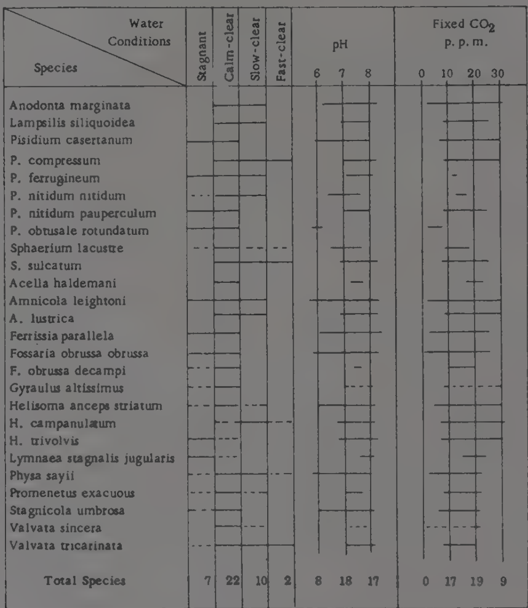


FIGURE 18. Relation of Mollusca to water conditions.

Collections 3 and 2 have a total population and amount of vegetation which are far greater than those of any other collection. This disproportion is best explained by the migration of the shoreline through the Station, accompanied by an accumulation of beach drift. It is noted in figure 2 that the ratio of shell fragments to vegetation in these collections greatly exceeds that of other collections. The changes in the specific assemblage along with the changes in vegetation and population indicates a steady lowering of the water level, corresponding migration of the shoreline through the Station, and ultimate disappearance of the lake from that particular site. The total vegetation would continue to increase but with a change from waterweeds to terrestrial vegetation. The appearance of *Hawaiia minuscula* supports this conclusion. The period during which the shoreline was present at Station 1 is represented by collections 3 and 2, where, in addition

to the indigenous population, there was considerable accumulation of shells and shell fragments as beach drift. Such an accumulation indicates that the prevailing winds were from the northwest.

The steady lowering of the level of the lake would result in the transition from a freshwater environment directly to a terrestrial environment without the development of swampy conditions. The absence of a peat layer and of those species more typical of a swampy environment show that this was the case. Since there is a gradual but continuous slope from the margins of the lake through Station 1 toward the site of the present lake, it is not expected that swampy conditions would have developed.

At Station 2 the upper surface is approximately at the same level as the upper surface of Station 1. This area, however, represents a broad, flat embayment,

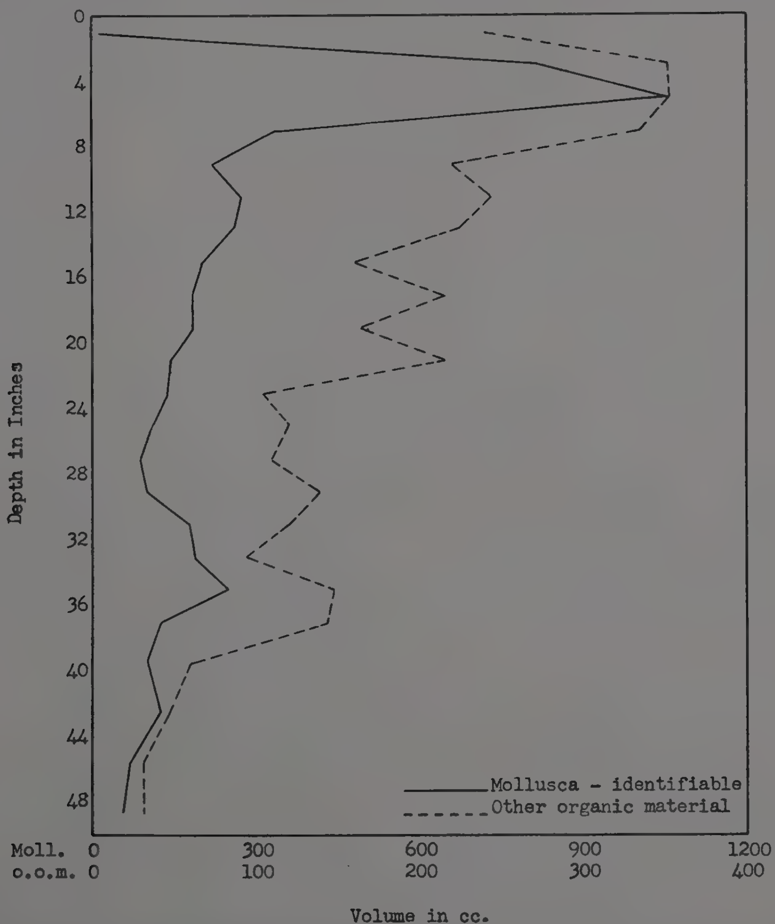


FIGURE 19. Graphic representation—vertical variation of Mollusca and other organic material in the Newell Lake deposit.

lacking the slope just discussed for Station 1. The lowering of the level of the water would result in shallow conditions which would extend over the entire embayment and most likely segregate the embayment from the main body of the lake. Thus, swampy conditions might be expected to develop. The much thicker layer of humus and the presence of peat at Station 16 (fig. 2), the appearance of such species as *Stagnicola umbrosa*, *Helisoma trivolvis*, *Succinea ovalis*, and *Pomatiopsis cincinnatiensis*, definitely point to a swampy environment. The presence of land snails at Station 2 indicates a continual presence of moist conditions, whereas at Station 1 only a single specimen of *Hawaiia minuscula*, a species which will survive under dry conditions, further proves the lack of low, moist, swampy conditions at Station 1.

AGE AND CORRELATION

General Statement

A comparison of the fauna studied with other faunas, both living and fossil, provides further understanding of the environment and some insight into the relative age of the Newell Lake deposit. Several representative faunas have been chosen in which the assemblage approximates that of the fauna at Station 1. In each list, the nomenclature has been brought up to date.

Living Fauna

North Star Lake, Itasca County, Minnesota.—The molluscan fauna collected by Baker (1935) from North Star Lake show a marked similarity to that of Pleistocene Newell Lake. In his discussion he states, "It is believed by the writer that many of the fossil faunas of the Illinoian Pleistocene especially in the loess deposits, lived under conditions comparable to those now found in northern Minnesota and southern Canada." In addition to the living fauna, *Gyraulus altissimus* was collected from the marl in Little North Star Lake. Several terrestrial species were also listed of which *Oxyloma retusa* was found along the shore.

North Star Lake is a deep glacial lake with rapidly descending shores. Molluscan life in the lake is largely within the 2 meter contour and practically ceases at the 4 meter contour. The list consists of the following species.

Anodonta kennicotti Lea
Anodonta marginata Say
Anodontoides modestus (Lea)
Lampsilis siliquoidea (Barnes)
Lampsilis siliquoidea rosacea (DeKay)
Sphaerium sulcatum (Lamarck)
Sphaerium truncatum (Linsley)
Pisidium sp.
Valvata tricarinata (Say) (111)
Amnicola limosa porata Say
Amnicola walkeri Pilsbry
Amnicola lustrica decepta F. C. Baker
Lymnaea stagnalis jugularis Say
Bulimnea megasoma (Say)
Acella haldemani ("Deshayes" Binney)
Fossaria obrussa decampi (Streng)
Helisoma anceps striatum (F. C. Baker)
Helisoma trivolvis macrostomum (Whiteaves)
Helisoma campanulatum (Say)
Planorbula armigera (Say)
Promenetus exacuous (Say)
Gyraulus deflectus obliquus (DeKay)
Gyraulus parvus (Say)
Gyraulus altissimus (F. C. Baker)
Gyrculus crista (Linnaeus)
Ferrissia parallela (Say)
Ferrissia fusca (C. B. Adams)
Physa gyrina Say
Oxyloma retusa Lea

Pleistocene Faunas

Rush Lake, Logan County, Ohio.—Baker (1920) describes the fauna collected by Dr. M. M. Leighton from Rush Lake as post-Wisconsin in age and concludes ". . .the Ohio deposit may, therefore, be considered as having lived in a larger Rush Lake, perhaps not long after the ice had disappeared from Ohio."

This fauna is of particular interest from the standpoint of its proximity, its age, the area of collection within the deposit, and the similarity of the fauna.

The shells were obtained from an exposure in an artificial ditch which drains into the lake a situation almost identical with Station 1 in the Newell Lake deposit. The list of species is:

Anodonta sp.—fragments
Sphaerium lacustre (Müller)—a dozen odd valves
Sphaerium sulcatum (Lamarck)—abundant
Pisidium casertanum (Poli)—2 valves
P. compressum Prime—common, almost abundant
P. ferrugineum Prime—a score
P. nitidum Jenyns—the most abundant species of the Sphaeriidae
P. nitidum pauperculum (Sterki)—2 valves
P. variabile Prime—about as common as *P. compressum*
Valvata sincera (Say)—3 specimens out of 20,000
V. tricarinata (Say) (111)—one of the most abundant species
V. tricarinata (Say) (101)—about 10 percent of the carinate *Valvata*
V. tricarinata (Say) (100)—a single specimen
Amnicola walkeri Pilsbry—not common, about 50 in a quart of material
A. leightoni F. C. Baker—with *A. lustrica* the most abundant species
A. lustrica Pilsbry—with *A. leightoni* nearly 40 percent of the total
Stagnicola palustris (Müller)—a single broken specimen
Fossaria obrussa decampi (Streng)—quite common
Helisoma anceps (Menke)—a fairly abundant species
H. anceps striatum (Baker)—about 10 percent of the *H. anceps*
Gyraulus altissimus (F. C. Baker)—after *A. lustrica* and *A. leightoni* is one of the most abundant shells in this deposit
G. deflectus (Say)—3 adult individuals
G. hirsutus (Gould)—a single specimen
Promenetus exacuous (Say)—fairly common
Ferrissia parallela (Haldeman)—a single specimen
Physa anatina Lea—adults not common, immature shells are almost abundant.

University of Illinois, Urbana, Illinois.—The fauna of this deposit occurs in marl overlying glacial till of Early Wisconsin age. Baker (1918b) states ". . . the relation of this marl to the till suggests that the pond or lake may have been inhabited by the mollusks when the late Wisconsin ice was resting at the Valparaiso moraine. . . . The fauna from these marls also indicates a cooler climate when the pond was occupied by the living mollusks, the southern limit of distribution of several of the species now being at considerable distance north of the locality." Baker's annotated list of species follows.

Sphaerium rhomboideum Prime—a portion of one right valve
Sphaerium occidentale Prime—one valve
Sphaerium lacustre (Müller)—a single valve
Pisidium nitidum Jenyns—the most abundant mollusk of the marl
P. ferrugineum Prime—next to *P. nitidum* is the most abundant
P. obtusale C. Pfeiffer—a few small specimens
P. variabile Prime—one valve
P. adamsi affine Sterki—a single valve
Valvata sincera (Say)—quite common
V. tricarinata (Say)—not common
Stagnicola reflexa (Say)—very abundant and variable
S. caperata (Say)—numerous, mostly mature
Fossaria obrussa decampi (Streng)—common

Helisoma trivolvis Say—not common, majority of individuals are immature
Gyraulus parvus urbanensis Baker—occurred sparingly
G. altissimus—a few adult individuals and a number of young and immature specimens
Physa sayii Tappan—a single immature shell
P. gyrina (Say)—occurs in abundance; the greater number are immature.

McKay Lake, Ottawa, Ontario, and Colton Lake, Renfrew County, Ontario.—The lists of species of these two deposits show similarities to the Newell Lake deposit. Whittaker (1921) places these deposits as recent and states that the deposit of McKay Lake appears to be much older than that of Colton Lake. The fossil lists are:

Colton Lake	McKay Lake
Pisidium casertanum (Poli)	*Pisidium casertanum* (Poli)
P. compressum Prime	. . . .
Valvata sincera (Say)	. . . .
V. tricarinata (Say)	*Valvata tricarinata* (Say)
Amnicola limosa Say	*Amnicola limosa* Say
A. leightoni F. C. Baker	*A. leightoni* F. C. Baker
A. lustrica Pilsbry	. . . .
. . . .	*Fossaria galbana* (Say)
. . . .	*F. obrussa* (Say)
Fossaria obrussa decampi (Streng)	. . . .
. . . .	*Helisoma anceps* (Menke)
Helisoma campanulatum (Say)	*H. campanulatum* (Say)
Gyraulus altissimus (F. C. Baker)	*Gyraulus altissimus* (F. C. Baker)
G. deflectus (Say)	. . . .
Physa gyrina Say	*Physa gyrina* Say
. . . .	*Stenotrema monodon* (Rackett)
. . . .	*Triodopsis albolabris* Say
. . . .	*Anguispira alternata* (Say)
Helicodiscus parallelus (Say)	*Helicodiscus parallelus* (Say)
. . . .	*Succinea ovalis* Say

CONCLUSIONS

The age of the Newell Lake deposit can be placed as Wisconsin on the basis of age assignments of the faunas compared and by the presence of such extinct species as *Amnicola leightoni*, *Helisoma anceps striatum*, *Gyraulus altissimus*, and *Fossaria obrussa decampi*. *G. altissimus* is extinct in Ohio but may be living farther north. Similarly *F. obrussa decampi* is extinct in Ohio but occurs in North Star Lake, Minnesota, and other northern lakes.

The presence of outwash, north and south of Newell Lake, covered with till of late Wisconsin age (in the usage of Goldthwait and Forsyth; see La Rocque and Forsyth, 1957, p. 81, footnote) suggests the earliest date for the development of the initial lake stage to be late Wisconsin, probably at a time when the ice was standing at the Farmersville moraine. The sharp drop of the bottom at Station 12 (fig. 3) could have been the result of a plunge pool developed at the ice margin.

As the ice retreated, sedimentation was continuous and the clay layer was deposited and filled the basin. Development of the outlet would have resulted in the lowering of the lake level and the opening of the lake to drainage westward. This lowering of the level resulted in the development of the peat layer overlying the clay. The presence of Naiades in this peat layer suggests the opening of the outlet, allowing fish to migrate upstream to the lake. Examination of material from the peat layer yielded confirmatory fish scales and a single vertebra. This

layer provides the first record of molluscan life in the deposit. With the advent of Mollusca and the establishment of lime secreting plants such as *Chara*, deposition of the marl commenced and has proceeded to the present.

LITERATURE CITED

Archer, A. F. 1948. Land snails of the genus *Stenotrema* in the Alabama region. Geol. Survey Alabama Mus. Pap. 28. 85 pp.

Baker, F. C. 1911a. The molluscan fauna of Tomahawk Lake, Wisconsin. Trans. Wis. Acad. Sci. 17: 200–246.

———. 1911b. The Lymnaeidae of North and Middle America, recent and fossil. Chicago Acad. Sci., Spec. Paper 3. 58 pp.

———. 1916. The relation of mollusks to fish in Oneida Lake. New York Coll. Forestry, Tech. Pub. 4. 366 pp.

———. 1918a. The productivity of invertebrate fish food on the bottom of Oneida Lake, with special reference to mollusks. New York State Coll. Forestry, Tech. Pub. 9. 233 pp.

———. 1918b. Post-Glacial molluscs from the marls of Central Illinois. Jour. Geol. 26: 659–671.

———. 1920. Pleistocene Mollusca from Indiana and Ohio. Jour. Geol. 28: 439–457.

———. 1928. Fresh water Mollusca of Wisconsin. Wis. Geol. and Nat. Hist. Survey, Bull. 70, pt. 1. 507 pp.; pt. 2. 495 pp.

———. 1935. Land and freshwater Mollusca from North Star Lake and Vicinity, Itasca County, Minnesota. Amer. Midl. Nat. 16: 257–274.

Beauchamp, W. M. 1891. Notes on familiar mollusks. Nautilus 5: 52.

Berry, E. C. 1943. The Amnicolidae of Michigan: distribution, ecology, and taxonomy. Misc. Pub. Mus. Zool. Univ. Mich. 57. 68 pp.

Clench, W. J. 1925. The Physidae of the Au Sable River, Michigan. Mich. Acad. Sci. Arts & Let. 5: 399–403.

Dawson, Jean 1911. The biology of Physa. Behavior Monographs 1. 120 pp.

Dennis, C. A. 1928. Aquatic Gastropods of the Bass Island Region of Lake Erie. Ohio State Univ. Franz Theodore Stone Lab. Cont. 8. 34 pp.

Forsyth, Jane L. 1956. The glacial geology of Logan and Shelby counties, Ohio. Unpub. Ph.D. Dissertation, Ohio State Univ. 209 pp.

Franzen, D. S. and **A. B. Leonard** 1947. Fossil and living Pupillidae (Gastropoda Pulmonata) in Kansas. Univ. Kansas Sci. Bull. 31: 311–411.

Goodrich, C. 1931. The Mollusca of Michigan, Univ. Mus. Univ. Mich. Handbook Ser. 5. 120 pp.

Herrington, H. B. 1947. *Acella haldemani* in Ontario, Canada. Nautilus, 61: 20–25.

———. 1954. *Pisidium* species and synonyms, North America, north of Mexico. Nautilus, 67: 131–137.

Johnson, C. W. 1904. *Ancyli* adhering to water beetles. Nautilus, 17: 120.

La Rocque, A. 1952. Molluscan faunas of the Orleton Mastodon Site, Madison County, Ohio. Ohio Jour. Sci. 52: 10–27.

———. 1956. Variation of carinae in *Valvata tricarinata*. Nautilus, 70: 13–14.

——— and **Jane L. Forsyth.** 1957. Pleistocene molluscan faunules of the Sidney Cut, Shelby County, Ohio. Ohio Jour. Sci. 57: 81–89.

Leonard, A. B. 1950. A Yarmouthian molluscan fauna in the Midcontinent region of the United States. Univ. Kansas Paleo. Cont. Mollusca Art. 3: 1–48.

——— and **C. R. Goble.** 1952. Mollusca of the University of Kansas Natural History Reservation. Univ. Kansas Sci. Bull. 34: 1013–1055.

Moffet, J. W. 1943. A limnological investigation of the dynamics of a sandy wave swept shoal in Douglas Lake, Michigan. Trans. Amer. Microsc. Soc. 53: 1–23.

Morrison, J. P. E. 1932a. A report on the Mollusca of the Northeastern Wisconsin Lake District. Trans. Wis. Acad. Sci. Arts & Let. 27: 359–396.

———. 1932b. Studies on the life history of *Acella haldemani* ('Desh.' Binney). Trans. Wis. Acad. Sci. Arts & Let. 27: 397–414.

Ortmann, A. E. 1919. A monograph of the Naiades of Pennsylvania, part III. Mem. Carnegie Mus. 8: 384 pp.

Robertson, A. D. 1915. The Mollusca of Georgian Bay. Cont. to Can. Biol., Supp. to 47th Ann. Rept., Canada Dept. Marine and Fisheries. 95–111.

Russell, L. S. 1934. Pleistocene and post-Pleistocene molluscan faunas of southern Saskatchewan (with description of a new species of *Gyraulus* by F. C. Baker). Can.-Field Nat. 48: 34–37.

van der Schalie, H. 1953. Mollusks from an interglacial deposit (Sangamon? age) in Meade County, Kansas. Nautilus, 66: 80–90.

Whittaker, E. J. 1921. The fossil molluscan faunas of the marl deposits of the Ottawa District. Geol. Survey Canada Bull. 33: 59–79.

CRAYFISHES OF THE CHEAT RIVER WATERSHED WEST VIRGINIA AND PENNSYLVANIA PART I. SPECIES AND LOCALITIES[1]

FRANK J. SCHWARTZ AND WILLIAM G. MEREDITH
Chesapeake Biological Laboratory, Solomons, Md. and *Mount St. Mary's College, Emmitsburg, Md.*

Subsequent to a comprehensive survey of the fish fauna of the Cheat River watershed of the Monongahela-Ohio River systems in West Virginia, it was possible, during the period of March 30 to July 20, 1956, to obtain a similar insight into the stream crayfish fauna of this watershed. Although the main field efforts occurred between the dates cited, sporadic collections were made as late as October 14, 1956.

The subject matter, because of the magnitude of the data on localities, ecology, and abundance, has been broken into two parts; Part I deals with the species, localities and distribution records while Part II will deal with the ecology, physiography, and explanations of the species distributions found in this watershed. As will be discussed in more detail in Part II, barriers, pollution, topography and other ecological factors have all contributed heavily in determining the distributions of the crayfishes within this area of West Virginia.

The crayfish faunas, as is true of other animal faunas, have received little study in West Virginia. Through the efforts of field excursions by Faxon (1914), Hay (1899, 1902), Ortmann (1905, 1906, 1913, 1931), Turner (1926) and Williamson (1901) into the state or parts of the Monongahela system, while studying the crayfish faunas of Maryland, Pennsylvania, Ohio and elsewhere, knowledge exists of the crayfishes of West Virginia. Newcombe's (1924) effort stands as the only work which attempts to compile a list of the crayfishes from all systems of the state. Since that time there have been few if any efforts to collect or study the crayfishes either of a part or of the entire state.

The Data

Collections and numbers.—Generally, collections were made downstream from south to north to take advantage of receding water levels with the advent of summer. All numbers cited herein bear an FJS connotation and run consecutively from 437–667, with sporadic additions. The 20 early collections of 383 specimens, dating 1890–1905, of *Cambarus bartoni carinirostris* bear U.S.N.M. labels and are so noted. A total of 233 collections comprised of two species totaling 1424 specimens was made throughout the six counties included in the watershed. Fifteen collections were made within the Fayette County, Pennsylvania, portion of the watershed. West Virginia collections, by county, were: Monongalia 3, Pocahontas 8, Preston 76, Randolph 51 and Tucker 80. Of these collections 153 (66%) contained crayfish while 80 (34%) did not. *Cambarus b. bartoni* occurred alone in 138 collections. *Orconectes obscurus* was found alone in 34 collections. *C. b. bartoni* and *O. obscurus* occurred together in only 19 collections. Those collections marked by an asterisk (*) did not possess crayfish samples. The localities are indicated on figure 1, which depicts the Cheat River watershed of West Virginia and Pennsylvania and its position in relation to the remainder of West Virginia.

Likewise, in order to handle the mass of data, the locality, ecological data, the number, sex and form of each species captured at a locality has been placed together to permit closer scrutiny of the conditions affecting the abundance or presence of each species.

[1]Contribution No. 125, Maryland Department of Research and Education, Solomons, Maryland.

The Crayfishes

Cambarus bartoni bartoni.—*C. b. bartoni* appeared within the Cheat River watershed in 138 collections: Pennsylvania, Fayette County 13; West Virginia, Monongalia County 2, Pocahontas County 4, Preston County 40, Randolph County 39, Tucker County 40. Within these series of collections there were 1155 specimens of *bartoni* represented by 575 form I males, 44 form II males and 536 females. This species was thus not only the most abundant of the two actually captured during the survey but was also the most widespread. However, close scrutiny of the distribution data will illustrate the absence of this species from the highly polluted center of the watershed.

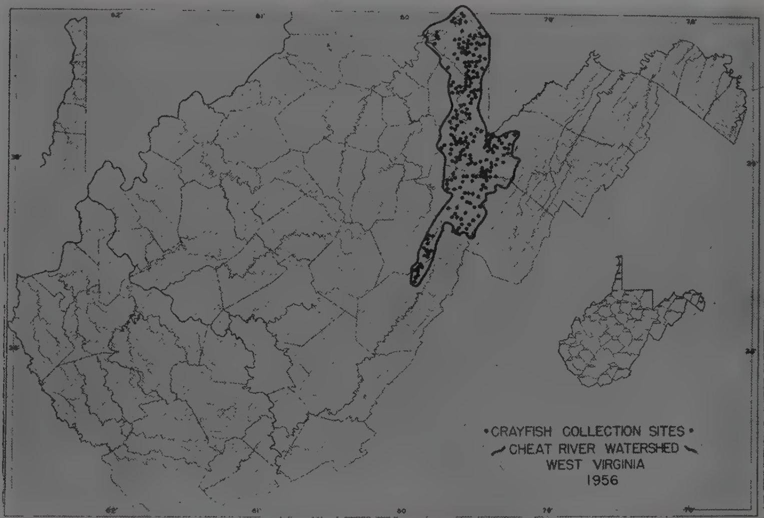


FIGURE 1. Location of the Cheat River Watershed, West Virginia and Pennsylvania, and 233 Crayfish Collection sites, 1956.

Literature records occur for this species at Davis (Blackwater River, Tucker County 6 ♂♂ II, 6 ♀♀, August 2, 1905, Faxon 1914: 131) and Parsons (Shavers Fork, Tucker County, Ortmann 1906: 382).

Cambarus bartoni carinirostris.—This subspecies of *C. bartoni* was first taken by W. P. Hay in Gandy Creek near Osceola, Randolph County, West Virginia, July 12, 1899 (USNM 23962, Paratype MCZ 7399) and at that time was abundant in the main streams of the Tygart and Cheat Rivers, with the Cheat River as its center of distribution (Faxon 1914: 386). Faxon (1914) also lists it taken at Albright (Cheat River, Preston County) by Hay. Ortmann (1931: 139) cites 1 ♂ II, 2 ♀♀ taken on August 2, 1905, in Shavers Fork, Parsons, Tucker County, and noted that those *bartoni* in the Blackwater River at Davis, West Virginia, were typical *C. bartoni* and not *C. b. carinirostris*. The latter is contrary to Dr. Horton H. Hobbs determinations of 1954 wherein he examined these specimens deposited in the U.S.N.M. (see Tucker County records) and has identified the Blackwater River specimens as *C. b. carinirostris*. Faxon (1914: 384–385) describes *carinirostris* and separates it from *C. b. bartoni* as follows:

> Rostrum of medium length, very broad, nearly plane or slightly excavated above and with a more or less distinct, median longitudinal carina, acumen short broad with concave sides, its tips strongly upturned. Carapace with a spinulose angle below the eye, branchostegian spine obsolescent; areola of moderate width. Telson bi- or trispinose on each side. Antennae when expanded backward reaching beyond middle

of abdomen. Chelepids stout and heavy, chelae broad and strong, heavily punctate above and below; inner margin of hand obscurely serrato-denticulate; fingers usually gaping at the base, strong down curved, pitted in lines, upper surface heavily ribbed, otherwise like *C. bartoni*.

C. b. carinirostris differs from *C. b. bartoni* in carapace is little more cylindrical rostrum harder and flatter and usually furnished near the tip with a median longitudinal carina. This carina is well defined and extends from near the acumen backward to about the middle of the broad flat surface of the rostrum. It is generally followed by one ill defined and very shallow foveola, sometimes reduced to a low elevation between the lateral angles of the rostrum or wonting.

Thus, the specimens determined as *carinirostris* by Hay and Faxon and checked by Hobbs, on reexamination most do not illustrate a distinct median longitudinal carina. A few specimens, with a little imagination, seem to have the elevated carina followed by the shallow foveola. However, until this subspecies status is examined thoroughly, the determination listed herein as *carinirostris* have been kept, but are not necessarily in agreement with the authors. The above differences or absence of characters suggest that perhaps the subspecies should not be recognized but a matter that will not be settled herein.

Assuming the original identifications are correct *C. b. carinirostris* was previously (1895 1905) collected in the Cheat River watershed. Of the 20 collections currently at the U.S.N.M. comprised of 344 specimens, none were collected from the Pennsylvania portion of the Cheat River watershed. Within West Virginia the following county collections are noted: Pocahontas 3, Preston 1, Randolph 11, Tucker 4, with one collection from the watershed from either Randolph or Pocahontas County. Ninety-seven form I males, 83 form II males, 141 females, 9 immature males, 7 immature females and 46 sex undetermined specimens comprised the samples.

Cambarus carolinus.—*Cambarus carolinus*, a burrowing species (Ortmann 1906: 416; 1931: 149), was not encountered in this survey, however, Ortmann (1931: 147) lists *C. carolinus* captures at Coopers Rock, Mount Chateau, Monongalia County (1 ♀, August 7, 1912) and at Parsons (Cheat River), Tucker County. *C. carolinus* was originally described as *C. carolinus dubius* by W. P. Hay (1902: 38, Type MCZ 23631) from Cranberry Summit (now Terra Alta, Preston County, West Virginia).

Orconectes obscurus.—*Orconectes* (=Faxionus=Cambarus) *obscurus* (Hobbs 1942) is reported in the literature from Ices Ferry (present bridge site across Cheat Lake, Monongalia County, West Virginia) by Faxon (1914: 374) and Newcombe (1924: 284). Currently *obscurus* was collected at 34 stations within the watershed. Pennsylvania, Fayette County 4; West Virginia, by counties, Monongalia 2, Preston 6, Randolph 4, Tucker 18. A total of 269 specimens of this species composed of 59 form I males, 76 form II males and 134 females were captured. Generally, this species will be noted to occur in the larger foothill streams. Its absence from the central highly polluted region is likewise obvious. *O. obscurus* is replaced in the smaller tributary or faster flowing streams by *C. b. bartoni* with which it was found at 19 localities.

List of Localities, Habitat Descriptions and Species Numbers by Sex or Form of the Crayfish Collections from the Cheat River Watershed of West Virginia and Pennsylvania

Pennsylvania, Fayette County

(Temperatures for air and water are expressed in degrees Fahrenheit).

437 Big Sandy Creek just W of Elliottsville, Pa., on Rt. 381, 5–12–56; Bottom boulder, rock and sand; Flow 40 cu ft/sec (abb. cfs below); Temp, air 72, water 72; Depth 4′; Width 40′; Species: *bartoni*, 3♂♂ I, 2 ♀♀.

438 Big Sandy Creek 0.9 mi W of Elliottsville, Pa., 5–12–56; Rock sand bottom; Flow 10 cfs; filamentous algae; Temp, air 62, water 54; Depth 3′; Width 12′; Species: *bartoni*, 7 ♂♂ I, 1 ♀; *orconectes*, 1♂ I, 2 ♀♀ in Berry.

439 Mill Cr. 2.0 mi E of Elliottsville, Pa., 5-12-56; Rock, rubble, sand, algae; Flow 15 cfs; Temp, air 74, water 53; Depth 4′; Width 25′; Species: *bartoni*, 1 ♂ I; *orconectes*, 4♂♂ I, 2 ♂♂ II.

440 Laurel Cr. 1.5 mi NW of Elliottsville, Pa., 1 mi NW of Church, W of Elliottsville on Mill Run School Road, 5–12 56; Bottom boulder and rock, Temp, air 82, water 54; Depth 2′; Flow 50 cfs; Species: *bartoni*, 3♂♂ I, 1 ♂ II.

441 Mill Cr. at Mill Cr. School 1.5 mi NW of Elliottsville near Laurel Cr. jct., 5–12–56; Rock, rubble, sand; Temp, air 82, water 56; Flow 30 cfs; Depth 2′; Width 25′; Species: *bartoni*, 3 ♂♂ I, 3 ♀♀.

444 Big Sandy Cr. ¾ mi N of Elliottsville on Rt. 381, 5–20–56; Rock, rubble; Temp, air 72, water 45; Flow 20 cfs; Depth 1′; Width 50′; Species: *bartoni*, 1 ♂ I, 2 ♀♀; *orconectes*, 3 ♂♂ I, 1 ♂ II.

445 McIntyre Run at Sandy Cr. School on Scotts Run Road, 5–20–56; Rock, rubble, sand; Filamentous algae; Temp, air 74, water 48; Flow 5 cfs; Depth 5′; Width 10′; Species: *bartoni*, 4 ♂♂ I, 4 ♀♀.

446 Braddock Cr. ¾ mi W of Chalk Hill and Rt. 40, 5–20–56; Bottom rock, boulder; Filamentous algae; Temp, air 72, water 48; Flow 5 cfs; Depth 1′; Width 5′; Species: *bartoni*, 5 ♂♂ I, 2 ♂♂ II, 3 ♀♀.

447 Stony Run ¾ mi E of Elliottsville and S of Rt. 381 Elliottsville to Farmington, 5–20–56; Bottom rock, boulder ; Filamentous algae; Temp, air 78, water 50; Flow 20 cfs; Depth 2′; Width 30′; Species: *bartoni*, 3 ♂♂ I, 2 ♂♂, II, 6 ♀♀.

448 Feik Run, Trib. of Little Sandy Cr. ¼ mi N of W. Va. line and 5 forks, 5–20–56; Bottom rock, rubble and sand covered with algae; Temp, air 78, water 49; Flow 30 cfs; Depth 2′; Width 30′; Species: *bartoni*, 2 ♂♂ I, 4 ♀♀.

449 Glades Run 1 mi NW of Rt. 26 to Glade Farm, 500′ N of Pa.—W. Va. line, 5–20–56; Bottom clay covered with algae; Temp, air 82, water 51; Flow 10 cfs; Depth 2′; Width 10′; Species: *bartoni*, 1 ♂ I, 5 ♀♀.

453 Little Sandy Cr. E of Gibbon Glades on Co. Road from Gibbon Glades to Clifton Mills, 5–20–56; Bottom rock, boulder; Temp, air 78, water 52; Flow 30 cfs; Depth 2′; Width 30′; Species: *bartoni*, 11 ♂♂ I, 1 ♂ II.

644 Feik Run at Pa.—W. Va. State Line N of Rt. 26 and Glade Farms, 7–18–56; Bottom mud, rock with *Vallisneria*; Temp, air 67, water 59; Flow 5 cfs; Depth 1–2′; Width 10′; Species: *bartoni*, 1 ♂ II.

652 Big Sandy Cr. on Pa.—W. Va. State Line, W of Rt. 381 Pa. on W. Va. Co. Rt. 4/2, 7–19–56; Bottom flat rock with long sand stretches; Temp, air 72, water 65; Flow 5 cfs; Depth 2′; Width 60′; Species: *orconectes*, 1 ♀.

665* Hope Hollow Cr. Trib. to Cheat R. 1 mi E of Pt. Marion, Pa. bridge, 7–20–56; Bottom rubble highly polluted, color red; Temp, air 75, water 69; Flow 5 cfs; Depth 1′; Width 5′.

West Virginia, Monongalia County

663 Coles Run, Trib. to middle backwater Cheat Lake, 7–20–56. Bottom bedrock; Temp, air 79, water 66; Flow 5 cfs; Depth 1′; Width 10′; Species: *bartoni*, 1 ♂ I, 1 ♀; *orconectes*, 2 ♂♂ I, 6 ♂♂ II, 1 ♀.

664 Rubles Run, Trib. to Backwater 3 Cheat Lake near Pa.—W. Va. State line 2 mi E Pt. Marion, Pa. on Rt. 71/1, 7–20–56; Bottom bedrock and rubble; Temp, air 87, water 71; Flow 5 cfs; Depth 2′; Width 20′; Species: *orconectes*, 4 ♂♂ I, 2 ♂♂ II, 3 ♀♀.

666 Cheat Lake above Quarry Run entry, 3–30–56; Bottom sand; Temp, air 30, water 34; Flow 40 cfs; Depth 20′; Width 20′; Species: *bartoni*, 2 ♂♂ I.

West Virginia, Pocahontas County

460 Black Cr. Headwaters of Shavers Fork 1 mi S of Spruce, W. Va., 5–31–56; Bottom rock and boulder; Temp, air 74; water 54; Flow 5 cfs; Depth 2′; Width 10′; Species: *bartoni*, 18 ♂♂ I, 1 ♂ II, 23 ♀♀.

461 Shavers Fork S of Black Cr. entry 1 mi S of Spruce, W. Va., 5–31–56; Bottom rock and boulder; Temp, air 74, water 54; Flow 10 cfs; Depth 2′; Width 10′; Species: *bartoni*, 1 ♂ I, 1 ♂ II, 6 ♀♀.

462* Shavers Fork 300′ N of Black Run 1 mi S of Spruce, W. Va., 5–31–56; Bottom rock, rubble and sand with filamentous algae; Temp, air 74, water 54; Flow 20 cfs; Depth 2′; Width 20′.

463 Shavers Fork at Spruce at little dam now falling apart, 5–31–56; Bottom sand, rock and boulder; Temp, air 79, water 56; Flow 25 cfs; Depth 3′; Width 50′; Species: *bartoni*, 7 ♂♂ I, 1 ♂ II, 3 ♀♀.

464* Unnamed Trib. enters NW–W into Shavers Fork at Spruce, 5–31–56; Bottom bedrock with algae; Temp, air 79, water 59; Flow 5 cfs; Depth 1′; Width 10′.

465 Shavers Fork at R.R. mile post 37 just S of Rocky Cr., 5–31–56; Bottom rock, gravel and sand with algae; Temp, air 74, water 66; Flow 30 cfs; Depth 2′; Width 30′; Species: *bartoni*; 2 ♂♂ I, 6 ♀♀.

466* Second Fork of Shavers Fork RR mile post 35, 5–31–56; Bottom sand; Temp, air 74, water 65; Flow 10 cfs; Depth 2′; Width 20′.

467* Shavers Fork between bridge mile post RR 35 and mouth second Fork, 5–31–56; Bottom sand; Temp, air 74, water 65; Flow 5 cfs; Depth 2′; Width 75′.

USNM 23956 Cheat Bridge, U.S. Fish Comm. acc. 36745, Hay, Faxon, Hobbs determinations, 7–25–99. Species: *carinirostris*, 9 ♂♂ I, 5 ♂♂ II, 6 ♀♀.

USNM 23971 Cheat Bridge, Faxon det., 7–24–99; Species: *carinirostris*, 3 ♂♂ I, 1 ♂ II, 1 ♀ in Berry.

USNM 28579 A Spring between Durbin and Cheat Bridge 1899; Species: *carinirostris*, 2 ♂♂ I.

USNM 28604 Cheat Bridge, Hay. 7–24–99; Species: *carinirostris*, 1 ♀.

West Virginia, Preston County

442 Hazel Run 1 mi NW Hopewell and Rt. 73 to Bruceton Mills, 5–11–56; Bottom sand, rock and mud; Temp, air 80, water 45; Flow 10 cfs; Depth 3′; Width 20′; Species: *bartoni*, 1 ♂ I, 1 ♂ II, 1 ♀.

443 Hazel Run on Rt. 73, 2 mi W of Bruceton Mills, ¾ mi W of Hopewell, 5–31–56; Bottom rock, sand and mud; Temp, air 80, water 54; Flow 10 cfs; Depth 2–5′; Width 15′; Species: *bartoni*, 2 ♂♂ I, 5 ♀♀.

450 Glade Run ¾ mi NW of Rt. 26 and ¾ mi NW Shady Grove School, 5–20–56; Bottom rock and boulder; Temp, air 82, water 54; Flow 20 cfs; Depth 2′; Width 10′; Species: *bartoni*, 4 ♀♀.

451 Trib. to Big Sandy Cr. ½ mi NW of Clifton Mills on Rt. 381 to Elliottsville,5–20–56; Bottom boulder and rock covered with filamentous algae; Temp, air 80, water 54; Flow 20 cfs; Depth 2′; Width 10′; Species: *bartoni*, 1 ♂ I, 3 ♀♀.

452* Little Sandy Cr. 1½ mi N of Clifton Mills on Rt. 381 at Bridge 8: 1936; 5–20–56; Bottom boulder, rock, rubble with filamentous algae; Temp, air 78, water 58; Flow 15 cfs; Depth 2′; Width 30′.

585 Flag Run at Cool Spring, W. Va., Rt. US 5/50, 2 mi W Macomber, 7–12–56; Bottom boulder and bedrock; Temp, air 56, water 56; Flow 10 cfs; Depth 1′; Width 15′; Species: *bartoni*, 3 ♂♂ I, 7 ♀♀.

586 Trib. to Cheat R. ¾ mi E of Macomber on US 50, 7-12-56; Bottom flatrock; Temp, air 59, water 58; Flow 5–10 cfs; Depth ½′; Width 5′; Species: *bartoni*, 1 ♂ I, 1 ♀.

587* Buffalo Cr. Rt. US 50 at Macomber, 7–12–56; Bottom boulder and flatrock; Temp, air 65, water 61; Flow 10 cfs; Depth 1′; Width 15′.

588 Buffalo Cr. 1.5 mi SW Macomber on W. Va. 72, 7–12–56; Bottom bedrock; Temp, air 70, water 65; Flow 10 cfs; Depth 1′; Width 15′; Species: *bartoni*, 2 ♂♂ I, 4 ♀♀; *orconectes*, 1 ♀.

589 Buffalo Cr. at Etam on Co. Rt. 61, W. Va. 72, 7–12–56; Bottom bedrock; Temp, air 75, water 65; Flow 10 cfs; Depth 1′; Width 20′; Species: *bartoni*, 4 ♂♂ I, 1 ♀; *orconectes*, 1 ♀.

590 Buffalo Cr. above entry of Little Buffalo ¾ mi near Bucklick Run, 7–12–56; Bottom rubble; Temp, air 72, water 66; Flow 5 cfs; Depth ½′; Width 5′; Species; *bartoni*, 3 ♂♂ I, 5 ♀♀.

596* Cheat R. at Tucker-Preston Co. line Rt. 27/1, 7–13 56; Bottom rubble and sand with many *Dianthera* islands in it; Temp, air 66, water 69; Flow 30 cfs; Depth 2′; Width 250-300′.

597 Little Wolf Cr. S. of US 50 on Rt. Co. 110, ½ mi on Hardesty-Sell Rd., 7-13-56; Bottom bedrock, boulder; Temp, air 68, water 60; Flow 15 cfs; Depth 1′; Width 15′; Species: *bartoni*, 3 ♂♂ I, 5 ♀♀.

598 Wolf Cr. on Rt. US 50 at Hardesty, 7–13-56; Bottom bedrock and boulder; Temp, air 67, water 60; Flow 10 cfs; Depth 1′; Width 10′; Species: *bartoni*, 4 ♀♀.

599* Cheat R. on Rt. US 50, ½ mi NW of Erwin, 7–13–56; Bottom boulder, rubble and sand; Temp, air 68, water 69; Flow 30 cfs; Depth 3′; Width 300′.

600 Madison Run on US 50, ¾ mi NW of Erwin, 7–13–56; Bottom bedrock and boulders covered with algae; Temp, air 75, water 61; Flow 10 cfs; Depth 1′; Width 10′; Species: *bartoni*, 2 ♂♂ I, 5 ♀♀.

601* Pringle Run 1 mi S of La Rue on W side of Cheat River & Rt. 72, 7–13–56; Bottom bedrock and boulders; Temp, air 72, water 60; Flow 25 cfs; Depth 1′; Width 20′; heavy mine pollution.

602* Licking Run at LaRue, W. Va., 3 mi S of Kingwood on Rt. 72, 7–13–56; Bottom bedrock and boulder; Temp, air 72, water 60; red colored from heavy acid mine pollution; Flow 20 cfs; Depth 1′; Width 5′.

603* Morgan Run 1.2 mi SE of Kingwood on Rt. 72 to Cadell (2 mi S of Rts. 72 & 7 jct.), 7–13–56; Bottom rock and sludge; Temp, air 72, water 65; Polluted by mines and sewage; Flow 15 cfs; Depth 1′; Width 20′.

604* Morgan Run ¾ mi NW Snider and Rt. 26, 7–13–56; Bottom boulder; Temp, air 72, water 65; Red from mine pollution; Flow 5 cfs; Depth 1′; Width 10′.

605* Trib. of Morgan Run at Irona ½ mi NW of Rt. 26, 7–13–56; Bottom boulder; Temp, air 75, water 66; Red with mine pollution; Flow 10 cfs; Depth 1′; Width 10′.

606* Pringle Run headwaters at Tunnelton on Rt. 26, 7–13–56; Bottom boulder; Temp, air 76, water 66; Heavy mine pollution; Flow 5 cfs; Width 1′; Depth 2′.

607* Cheat R. at Rowlesburg below Saltlick Cr. entry and Rt. 51, 7–14–56; Bottom rock and rubble; Temp, air 73, water 67; Covered with algae and sludge; Flow 30 cfs; Depth 2′; Width 320′.

608 Saltlick Run 1 mi NE Rowlesburg near B&O Roundhouse at Rt. 51 crossing, 7–14–56; Bottom flat slippery rock, boulder, gravel; Temp, air 67, water 69; Flow 15 cfs; Depth 2′; width 15–20′; Species: *bartoni*, 4 ♂♂ I, 1 ♀.

609 Big Run approx. 2 mi NE Rowlesburg, a Saltlick Trib. on Co. Rt. 51, 7–14–56; Bottom bedrock, rubble; Temp, air 73, water 63; Flow 15 cfs; Depth 1′; Width 10′; Species: *bartoni*, 3 ♂♂ I, 2 ♀♀.

610 Spruce Run at Amblersburg RR Tunnel on Co. Rt. 51, 7–14–56; Bottom bedrock, boulder; Temp, air 65, water 65; Flow 10 cfs; Depth 3′; Width 10′; Species: *bartoni*, 5 ♂♂ I, 6 ♀♀.

611 Saltlick Run near Pine Grove School on Co. Rt. 51, 7–14–56; Bottom rock, rubble; Temp, air 72, water 67; Flow 15 cfs; Depth 2′; Width 15′; Species: *bartoni*, 3 ♂♂ I, 2 ♀♀.

612 Kinsinger Run 1 mi S Beatty School Co. Rt. 80, 7–14–56; Bottom rock, rubble, mud; Temp, air 68, water 66; Flow 10 cfs; Depth 2′; Width 8′; Species: *bartoni*, 4 ♀♀.

613 Saltlick Run at Beatty School Co. Rt. 51/4, 7–14–56; Bottom rubble; Temp, air 72, water 65; Flow 10 cfs; Depth 3′; Width 15′; Species: *bartoni*, 3 ♂♂ I, 2 ♀♀.

614 Saltlick Run 3 mi SW Terra Alta on Amblersburg Rt. 51, 7–14–56; Bottom rubble; Temp, air 68, water 65; Flow 5 cfs; Depth ½′; Width 8′; Species: *bartoni*, 6 ♂♂ I, 2 ♀♀.

615* Mountain Run, Trib. of Spruce Run 1.5 mi SW Rodamer, 7–15–56; Bottom clay, rubble; Temp, air 70, water 63; Flow 5 cfs; Depth 2′; Width 5′.

616 Spruce Run 1.3 mi SW Rodamer near Mountain Run, 7–15–56; Bottom flatrock, rubble; Temp, air 70, water 62; Flow 5 cfs; Depth 1′; Width 8′; Species: *bartoni*, 2 ♂♂ I, 1 ♀.

617* Stamping Ground Run S of Whitsell School, 7–15–56; Bottom sand, rubble; Temp, air 76, water 59; Flow 5 cfs; Depth 1′; Width 5′.

618* Joes Run ¾ mi W Whitsell School, 7–15–56; Bottom rubble and sand; Temp, air 77, water 66; Flow 10 cfs; Depth 1′; Width 10′; Active mines below this point.

619* Buffalo Cr. 1.5 mi SE of Rt. 7 and E of Kingwood Country Club, 7–15–56; Bottom rubble; Temp, air 77, water 65; Flow 10 cfs; Depth 1′; Width 5′; Strip mines below this point.

620* Buffalo Cr. 500′ below Spillway to Dam on Kingwood Country Club Golf Course, 7–15–56; Bottom rubble; Temp, air 81, water 74; Flow 10 cfs; Depth ½′; Width 10′; Sponge and algae growing.

621 Elsey Cr. 1 mi N Rt. 7/12, 2 mi S of Albright, 7–15–56; Bottom boulders; Temp, air 85, water 67; Flow 30 cfs; Depth 1′; Width 10′; Species: *bartoni*, 1 ♂ I.

622* Daugherty Run at S city limit of Albright, 7–15–56; Bottom rock and sludge; Temp, air 74, water 67; Green colored from runoff and ash pile; Flow 10 cfs; Depth 1′; Width 10′.

623 "Upper" Daugherty Cr. near Crane School on Co. Rt. 3/12, 7–15–56; Bottom boulder; Temp, air 75, water 60; Flow 20 cfs; Depth 1′; Width 20′; Species: *bartoni*, 1 ♂ I, 1 ♀.

624 Roaring Cr. at Lick Run School on Rt. 3, Brandonville Turnpike, 7-15-56; Bottom rock and Boulder; Temp, air 58, water 61; Flow 10 cfs; Depth 1′; Width 15′; Species: *bartoni*, 3 ♂♂ I, 5 ♀♀.

625 Daugherty Run at Dority on Brandonville Pike 7-15-56; Bottom rock rubble; Temp air 75, water 61; Flow 10 cfs; Depth 1′; Width 10′; Species: *bartoni*, 3 ♂♂ I, 1 ♀.

626* Roaring Run at Ruth Belle Mills, Rt. 26, 7-16-56; Bottom sludge, rock; Temp, air 70, water 63; Flow 15 cfs; Depth 1′; Width 20′; Water white colored from ash pile runoff.

627 Roaring Run 1 mi SW Lick Run School Co. Rt. 3/9, 7-16-56; Bottom boulder, moss; Temp, air 70, water 58; Flow 30 cfs; Depth 2′; Width 15′; Species: *bartoni*, 1 ♂ I, 1 ♀.

628 Lick Run near Lick Run School Rt. 3, 7-16-56; Bottom rock, rubble; Temp, air 72, water 60; Flow 15-20 cfs; Depth 2′; Width 10′; Species: *bartoni*, 13 ♂♂ I, 2 ♀♀.

629 Headwaters of Muddy Cr. 1 mi N near Piney Swamp Knob Co. Rt. 28, 7-16-56; Bottom bedrock; rubble; Temp, air 76, water 63; Flow 5 cfs; Depth 2′; Width 10′; Species: *bartoni*, 3 ♂♂ I, 2 ♀♀.

630* Muddy Cr. 1.5 mi SE X E of Cuzzart, 7-16-56; Bottom boulder and bedrock and moss; Temp, air 72, water 60; Flow 25 cfs; Depth 1′; Width 10′.

631 Muddy Cr. 1 mi SE of Cuzzart on Co. Rt. 28, 7-16-56; Bottom boulder and moss; Temp, air 75, water 61; Flow 30 cfs; Depth 1′; Width 10′; Species: *bartoni*, 2 ♀♀.

632 Muddy Cr. 1 mi S Centennary Church, 7-16-56; Bottom boulder and flatrock; Temp, air 80, water 65; Flow 20 cfs; Depth 1′; Width 15-20′; Species: *bartoni*, 4 ♂♂ I.

633 Muddy Cr. 1 mi SW of Guzeman on Co. Rt. 17, 7-16-56; Bottom bedrock and rock with algae; Temp, air 83, water 67; Flow 15 cfs; Depth 1′; Width 30′; Species: *bartoni*, 1 ♂ II.

634* Glade Run ¾ mi W Glade Meadow School and Rt. 26, 7-16-56; Bottom mud; Temp, air 75, water 72; Extreme mine pollution; Flow 1-5 cfs; Depth 1′; Width 5′.

635* Glade Run near Martin Cr. ¾ mi NW Rt. 26 and Deep Hollow School, 7-16-56; Bottom boulder; Temp, air 75, water 72; Red mine pollution; Flow 10 cfs; Depth 1′; Width 10′.

636* Martin Run 0.4 mi NW Rt. 26 and Deep Hollow School, 7-16-56; Bottom boulder; Temp, air 75, water 72; Red from deep and strip mine pollution; Flow 10 cfs; Depth 1′; Width 15′.

637* Muddy Cr. ½ mi S of Rt. 26 and Martin and Muddy Cr. jct., 7-16-56; Bottom boulder and mud; Temp, air 75, water 69; Red from mine pollution; Flow 20 cfs; Depth 2′; Width 20′.

638* Muddy Cr. ½ mi N of Ruth Belle Mill and 2 mi NW Rt. 26, 7-16-56; Bottom boulder and rock; Temp, air 75, water 71; Red from pollution; Flow 15 cfs; Depth 2′; Width 25′.

639 Beaver Cr. Headwaters ½ mi SW Mountain Dale and Rt. 11, 7-17-56; Bottom boulder, sand and moss; Temp, air 61 ,water 63; Flow 10 cfs; Depth 1′; Width 10′; Species: *bartoni*, 5 ♂♂ I, 2 ♂♂ II, 4 ♀♀.

640 Beaver Cr. Trib. of Little Sandy Cr. 0.5, 5 mi NW Cuzzart Rt. 5/10, 7-17-56; Bottom boulder and sand; Temp air 61 water 63; Red colored; Flow 10 cfs; Depth 1′; Width 10′; Species: *bartoni* 3 ♂ ♂ I.

641 Beaver Cr. at Bridge 2 on Co. Rt. 3/4, 1 mi NNW of Vale School, 7-17-56; Bottom boulder and sand; Temp, air 61, water 66; Flow 10 cfs; Depth 1′; Width 15′; Species: *bartoni*, 2♂♂ I, 2 ♂♂ II.

642 Little Sandy Cr. at Rt 26 Bridge 2 mi S of Bruceton Mills, 7-17-56; Bottom flatrocks; Temp, air 63, water 73; Flow 0-5 cfs; Depth 1′; Width 60′; Species: *bartoni*, 1 ♂ I, 3 ♀♀; *orconectes*, 4 ♀♀.

643 Headwaters of Hog Run 1 mi SSE of Clover School on Co. Rt. 26/9, 7-17-56; Bottom sand and rock; Temp, air 67, water 63; Flow 5 cfs; Depth 1′; Width 5′; Species: *bartoni*, 1 ♂ I, 1 ♀.

645* Cherry Run 0.3 mi E of Glade Farm near Spingeon School 7-18-56; Bottom mud; Temp, air 75, water 69; Flow 5 cfs; Depth 1′; Width 5′.

646* Mill Run at Hazelton Saw Mill Rt. 12, 7-18-56; Bottom mud, bedrock and boulders and moss; Temp, air 79, water 61; Flow 0-5 cfs; Depth 2′; Width 10′.

647* Hog Run near entry with Little Sandy Cr. 1 mi NW Hazelton Co. Rt. 5/7, 7-18-56; Bottom mud with Vallisneria; Temp, air 76, water 65; Flow 5 cfs; Depth 3′; Width 20′; Strip mines all around.

648 Little Sandy Cr. 1.5 mi E of Rt. 26 on Co. Rt. 3, 1.5 mi NW of Vale School, 7-18-56; Bottom

boulder and some sand; Temp., air 72, water 75; Flow 20 cfs; Depth 3′; Width 40′; Species: *bartoni*, 1 ♀; *orconectes*, 1 ♂ II.

649* Little Sandy Cr. approx. 2 mi N of Vale School 7–18–56; Bottom boulder; Temp, air 72, water 73; Flow 20 cfs; Depth 2′; Width 15′.

650* Little Sandy Cr. 2 mi NNE of Locust Grove School on Co. Rt. 5/13, 7–18–56; Bottom boulder, mud; Temp, air 80, water 75; Flow 10 cfs; Depth 3′; Width 20′.

651 Clifton Mills—Big Sandy Cr. Co. Rt. 8, 7–19–56; Bottom rock and sand; Temp, air 72, water 65; Flow 10 cfs; Depth 3′; Width 60′; Species: *orconectes*, 3 ♂♂ II, 1 ♀.

653 Headwaters of Laurel Cr. 1 mi E Valley School on Co. Rt. 2/1, 7–19–56; Bottom mud and rock; Temp, air 77, water 64; Flow 10 cfs; Depth 2′; Width 10′; Species: *bartoni*, 1 ♂ II.

654* Patterson Run Lake at Valley School Lake, 7-19-56; Bottom rock and mud with cattails at one end; Temp, air 75, water 69; Flow 5 cfs; Depth 15′+; Width 40′.

655 Laurel Cr. upstream from Greenville School, 7–19–56; Bottom mud; Temp, air 71, water 63; Flow 5 cfs; Depth 3′; Width 10′; Species: *bartoni*, 1 ♀.

656 Big Sandy Cr. at Bruceton Mills Dam, 7–19–56; Bottom bedrock and rock with Vallisneria; Temp, air 73, water 65; Flow 15 cfs; Depth 4′; Width 60′; Species: *orconectes*, 1 ♂ II, 2 ♀♀.

657 Laurel Run at Rt. 73, 5 mi W of Bruceton Mills, 7–19–56; Bottom boulder, rock; Temp, air 61, water 63; Flow 5 cfs; Depth 1′; Width 30′; Species: *bartoni*, 13 ♂♂ I, 1 ♂ II, 6 ♀♀.

658 Big Sandy Cr. at Rockville on Co. Rt. 14/1, 7–19–56; Bottom bedrock and huge boulders; Temp, air 70, water 73; Flow 30 cfs; Depth 2′; Width 125′; Species: *bartoni*, 1 ♀.

659* Trib. to SE of Big Sandy Cr. near Rockville at Waterfall, 7–19–56; Bottom bedrock outcrop; Temp, air 72, water 65; Flow 10 cfs; Depth 4′; Width 20′;.

660* Bull Run at Bull Run, 7–19–56; Bottom boulder and slimy algae; Temp, air 72, water 63; Red from mine waste; Flow 15 cfs; Depth 2′; Width 20′.

661* Cheat R. at Albright Dam and Rt. 26 Bridge, 7–20–56; Bottom boulder, mud; Temp, air 76 water 73; Flow 50 cfs; Depth 3′; Width 200′.

662* Cheat R. at Rt. 72, 2 mi W of Kingwood, 7–20–56; Bottom rubble rock with algae and Dianthera; Temp, air 70, water 70; Flow 40 cfs; Depth 2′; Width 400′.

USNM 28602 Muddy Cr. near Albright. H. Hay, 7–17–99; Species: *carinirostris*, 1 ♂ I.

West Virginia, Randolph County

454 Red Run 1 mi NW Cheat Bridge along Rt. US 250, 5–30–56; Bottom sand, tree branches, some algae; Temp, air 56, water 50; Flow 5 cfs; Depth 3′; Width 15′; Species: *bartoni*, 2 ♂♂ I, 4 ♀♀.

455 Cheat Bridge—Shavers Fork at US 250, 5–30–56; Bottom rock, boulder and sand; Temp, air 72, water 53; Flow 36 cfs; Depth 3′; Width 60′; Species: *bartoni*, 4 ♂♂ I, 2 ♂♂ II, 17 ♀♀.

456 Shavers Fork at mouth of Whitmeadow Run 1 mi N Cheat Bridge on USFS Rt. 47, 5–30–56; Bottom rock, boulders and some sand and *Dianthera*; Temp, air 74, water 55; Flow 40 cfs; Depth 4′; Width 60′; Species: *bartoni*, 2 ♂♂ I, 1 ♀.

457* Trib., no name between Stonecoal and Whitmeadow Cr. near Rt. 49, 5–30–56; Bottom rock, boulder; Temp, air 74, water 55; Flow 40 cfs; Depth 1′; Width 10′.

458 Stonecoal Cr. 500′ up from mouth jct with Shavers Fork, 5–30–56; Bottom bedrock of coal seam and boulders; Temp, air 74, water 55; Flow 20 cfs; Depth 1′; Width 20′; Species: *bartoni*, 5 ♂♂ I, 1 ♀.

459 Blister Run ½ mi E of Cheat Bridge along US 250, 5–30–56; Bottom rock and boulder; Temp, air 75, water 55; Flow 5 cfs; Depth 1′; Width 10′; Species: *bartoni*, 7 ♂♂ I, 3 ♀♀.

468 First Fork near entrance to Shavers Fork, 6–1–56; Bottom sand; Temp, air 55; water 51; Flow 30 cfs; Depth 2′; Width 30′; Species: *bartoni*, 6 ♂♂ I, 1 ♂ II, 5 ♀♀.

469 Shavers Fork N of first fork and S of Cheat Bridge, 6–1–56; Bottom rocky, boulder and sand; Temp, air 55, water 50; Flow 40 cfs; Depth 3′; Width 100′; Species: *bartoni*, 4 ♂♂ I, 1 ♀.

470* Fish Hatchery Cr. 1½ mi S of Cheat Bridge, 6–1–56; Bottom boulders and rock; Temp, air 56, water 50; Flow 40 cfs; Depth 2′; Width 15′; Water brown from rhododendron.

471 Whitmeadow Cr. on USFS Rt. 47 N of Cheat Bridge, 6–2–56; Bottom rock and boulder; Temp, air 45, water 48; Flow 40 cfs; Depth 1′; Width 15′; Species: *bartoni*, 7 ♂♂ I, 5 ♀♀.

472 Fishing Hawk Cr. at Bemis, 6–6–56; Bottom boulder and gravel; Temp. air 56, water 48; Flow 15 cfs; Depth 1′; Width 15′; Species: *bartoni*, 1 ♀.

473 Glady Fork 0.4 mi N of Glady on Co. Rt. 27, 6–6–56; Bottom rock and rubble; Temp. air 60, water 50; Flow 10 cfs; Depth 3′; Width 20′; Species: *bartoni*, 8 ♂♂ I, 5 ♀♀.

474 West Fork Glady Cr. 2.7 mi S of Glady near Beulah Co. Rt. 22/2, 6–6–56; Bottom rubble; Temp, air 64, water 50; Flow 5 cfs; Depth 1′; Width 10′; Species: *bartoni*, 5 ♂♂ I, 2 ♂♂ II, 7 ♀♀.

475 Louk Run near confluence with East fork Glady Cr. 2.8 mi SE Glady Rt. 1, 6–9–56; Bottom rubble and sand; Temp, air 73, water 53; Flow 5 cfs; Depth ½′; Width 10′; Species: *bartoni*, 1 ♂ I, 1 ♀.

476 East fork Glady Fork 2.8 mi SE Glady on Co. Rt. 22/1, 6–6–56; Bottom rock, rubble and *Dianthera*; Temp, air 70, water 65; Flow 20 cfs; Depth 4′; Width 20′; Species: *bartoni*, 7 ♂♂ I, 2 ♂♂ II, 8 ♀♀.

477* Elk Run 5 mi S of turn off to forest station on Rt. 14 walk down Chuffy Trail near Rt. USFS 35, 6–6–56; Bottom rock and rubble; Temp, air 80, water 50; Flow 5 cfs; Depth ½′; Width 10′.

478 Laurel fork down Chuffy Trail N of Elk Run, 5 mi S of Forest Sta. E of USFS Rt. 14, 6–6–56; Bottom rock and rubble; Temp, air 80, water 50; Flow 5 cfs; Depth —; Width 10′; Species: *bartoni*, 6 ♀♀.

479* 5 Lick Run ½ mi E of Forest station where road crosses creek Co. Rt. 40, 6–6–56; Bottom rubble; Temp, air 68, water 59; Flow 10 cfs; Depth 1′; Width 15′.

480 Laurel Fork at Cherry Grove U.S. Forest Station on Co. Rt. 40, 6–7–56; Bottom rock, rubble and algae; Temp, air 61, water 52; Flow 30 cfs; Depth 3′; Width 20′; Species: *bartoni*, 10 ♂♂ I, 5 ♂♂ II, 23 ♀♀.

481 Gandy Cr. 500′ S of opening for Sinks of Gandy near Co. Rt. 40, 6–7–56; Bottom rubble Temp, air 78, water 53; Flow 15 cfs; Depth 2′; Width 20′; Species: *bartoni*, 3 ♂♂ I, 3 ♀♀.

482* Outlet of Sinks of Gandy, 6–7–56; Bottom sand, muck and rock; Temp, air 77, water 54; Flow 10 cfs; Depth 3′; Width 20′.

483 Gandy Cr. S of Grants Run 10 mi S of Whitmer on Co. Rt. 41, 6–7–56; Bottom rock, boulder and filamentous algae; Temp, air 80; water 60; Flow 30 cfs; Depth 3′; Width 40′; Species: *bartoni*, 2 ♂♂ I, 3 ♀♀.

484 Gandy Cr. 5 mi S of Whitmer Co. Rt. 41, 6–7–56; Bottom bedrock, boulder; Temp, air 74, water 64; Flow 40 cfs; Depth 3′; Width 40′; Species: *bartoni*, 7 ♂♂ I, 12 ♀♀.

485 Gandy Cr. 1 mi NW of Whitmer, 6–7–56; Bottom boulder, rocks and filamentous algae. Temp, air 74, water 66; Flow 30 cfs; Depth 3′; Width 75′; Species: *bartoni*, 1 ♂ II, 13 ♀♀.

486 Dry Fork ¾ mi S of junction with Gandy Cr. near Whitmer Co. Rt. 29, 6–8–56; Bottom rubble; Temp, air 56, water 52; Flow 5 cfs; Depth ½′; Width 10′; Species: *bartoni*, 1 ♂ I, 1 ♀.

487 Dry Fork at Job. Rt. 29 below Stinking Cr., 6–8–56; Bottom rock and rubble; Temp, air 60, water 53; Flow 30 cfs; Depth 1′; Width 40′; Species: *bartoni*, 5 ♂♂ I, 9 ♀♀.

488 Dry Fork 1 mi W of Harmon on US 33/4, 6–8–56; Bottom boulder and rock; Temp, air 68, water 54; Flow 50 cfs; Depth 3′; Width 75′; Species: *bartoni*, 2 ♂♂ I, 10 ♀♀.

489* Horsecamp Run at Harman on US 33/32, 6–8–56; Bottom rock and boulder; Temp, air 66, water 55; Flow 5 cfs; Depth 1′; Width 10–15′.

490 Laurel Cr. below Wymer on Rt. US 33/4, 6–8–56; Bottom bedrock and boulder; Temp, air 80, water 62; Flow 15 cfs; Depth 3′; Width 75′; Species: *bartoni*, 2 ♂♂ I, 5 ♀♀.

491 Beaver Dam Run 5.2 mi S of Wymer and US 33/4 on Co. Rt. 27, 6–8–56; Bottom rubble, sand and algae; Temp, air 80, water 66; Flow 5 cfs; Depth 3′; Width 10′; Species: *bartoni*, 5 ♂♂ I, 5 ♀♀.

492 Laurel Run N of Beaver Dam Run entry (no road) 5.1 mi S of Wymer and 1 mi E of Co Rt. 27, 6–8–56; Bottom rock and rubble; Temp, air 80, water 64; Flow 10 cfs; Depth 3′; Width 40′; Species: *bartoni*, 2 ♂♂ I, 2 ♀♀.

493 Laurel Fork 10 mi S of Wymer on Co. Rt. 27, 6–9–56; Bottom rock rubble mud and algae; Temp, air 60, water 57; Flow 20 cfs; Depth 3′; Width 40′; Species: *bartoni*, 6 ♂♂ I, 2 ♂♂ II, 5 ♀♀.

494 Glady Fork 4 mi S of Rt. 33 near McCray Run and Co. Rt. 27, 6–9–56; Bottom rock, rubble and algae; Temp, air 80, water 64; Flow 20 cfs; Depth 2′; Width 40′; Species: *bartoni*, 1 ♂ I, 2 ♀♀.

495 Glady Fork 1 mi E Evinwood Rt. 33, 6–9–56; Rock, rubble and mud; Temp, air 80, water 67; Flow 20 cfs; Depth 2′; Width 40′; Species: *bartoni*, 2 ♂♂ I, 2 ♂♂ II.

496* Taylor Run on US 30 W of Wymer and Chestnut Grove, 6–10–56; Bottom boulder; Temp, air 54, water 75; Flow 5 cfs; Depth —; Width 15′.

497* Shavers Fork 1 mi W of Bowden on US 33/4, 6–10–56; Bottom rock, rubble and algae; Temp, air ?, water 54; Flow 5 cfs; Depth 3′; Width 90′.

498* Yellow Cr. 1 mi N of Forest Service Road 93 N of Rt. (US) 33 and Alpena, 6–10–56; Bottom conglomerate pebbles, sand and *selaginella*; Temp, air 74, water 57; Colored yellow; Flow 5 cfs; Depth 3′; Width 10′.

499* Otter Cr. N of Yellow Cr. entry 1 mi S of Forest Rd. 93 and Alpena, 6–10–56; Bottom sand; Temp, air 75, water 57; Flow 10 cfs; Depth 1′; Width 20′.

500 Condon Run Headwaters to Otter Cr. at end of Forest Rd. 93 1 mi S of US 33, 6–10–56; Bottom rubble and sand; Temp, air 75, water 57; Flow 5 cfs; Depth 1′; Width 10′; Species: *bartoni*, 1 ♂ I, 7 ♀♀.

503 Glady Fork at entrance of Panther Camp Run, 2 mi W of Sully on Co. Rt. 12, 6–12–56; Bottom rock and algae; Temp, air 73, water 67; Flow 15 cfs; Depth 5′; Width 60′; Species: *bartoni*, 3 ♂♂ I, 2 ♂♂ II, 3 ♀♀.

504 Glady Fork near Kuntsville approx. 5 mi NW of Sully and N of Co. Rt. 12, 6–12–56; Bottom rock, rubble, bedrock, *Chara* and *Vallisneria*; Temp, air 73, water 73; Flow 25 cfs; Depth 5′; Width 100′; Species: *bartoni*, 1 ♂ I.

505 Three Spring Run, Trib. to Glady Fork near Sully (approx. 3 mi) on Co. Rt. 27, 6–12–56; Bottom rubble; Temp, air 75, water 55; Flow 5 cfs; Depth 1′; Width 10′; Species: *bartoni*, 3 ♂♂ I, 4 ♀♀.

506 Dry Fork 2 mi NE of Harmon off Rt. 32 first bridge N of Town, 6–12–56; Bottom rock and rubble; Temp, air 74, water 70; Flow 10 cfs; Depth 1′; Width 80′; Species: *bartoni*, 1 ♂ I, 3 ♀♀.

507 Red Cr. on Rt. 32 at Tucker—Randolph Co. Line, 6–14–56; Bottom boulder; Temp, air 75, water 71; Flow 10 cfs; Depth 2′; Width 80′; Species: *bartoni*, 2 ♂♂ I, 1 ♀.

508 Dry Fork at Dry Fork 3 mi NW of Co. Rt. 32/7, 6–13–56; Bottom rock, boulders, sand and *chara* in pools; Temp, air 59, water 62; Flow 15 cfs; Depth 3′; Width 60′; Species: *orconectes*, 1 ♀.

547 Shavers Fork near Bowden on Rt. 33/4 W of National Forest Entrance, 6–30–56; Bottom rock and boulder; Temp, air 70, water 68; Flow 30 cfs; Depth 4′; Width 200′; Species: *bartoni*, 5 ♂♂ I, 1 ♀; *orconectes*, 19 ♂♂ II, 23 ♀♀.

548 Shavers Fork ¾ mi NE of Turkey Knob ridge S of USFS 38/9/3, 7–1–56; Bottom rock, rubble and algae; Temp, air 71, water 68; Flow 40 cfs; Depth 3′; Width 200′; Species: *bartoni*, 2 ♂♂ II; *orconectes*, 1 ♂ II, 3 ♀♀.

549* Shavers Fork near Canfield School on USFS Rt. 38, 7–1–56; Bottom rock, boulder, rubble, algae; Temp, air 73, water 68; Flow 30 cfs; Depth 2′; Width 125′; A mud-sand oxbow nearby.

550 Rattlesnake Run on USFS Rt. 38, 5 mi N of Rt. 33/4 to Elkins, 7–1–56; Bottom bedrock, boulders, algae; Temp, air 72, water 64; Flow 15 cfs; Depth 1′; Width 15′; Species: *bartoni*, 3 ♂♂ I, 13 ♀♀.

551 Little Black Fork at USFS jct 38–7 Rt., 7–1–56; Bottom bedrock-rock, algae; Temp, air 78, water 63; Flow 15 cfs; Depth 1′; Width 15′; Species: *bartoni*, 3 ♂♂ I, 2 ♀♀; *orconectes*, 1 ♀.

552 Shavers Fork below Clifton Run and USFS Rt. 39, 7–2–56; Bottom bedrock, boulder; Temp, air 71, water 70; Flow 40 cfs; Depth 2′; Width 120′; Species: *bartoni*, 1 ♂ I.

USNM 23693 Gandy Cr. at Osceola, Hay collector. Species: *carinirostris*, 7 ♂♂ I, 1 ♂ II, 4 ♀♀.

USNM 23958 Cheat R. near the pike, Faxon determined, 7–25–99: Species: *carinirostris*, 25 specimens.

USNM 23961 West Fork Glady Cr., 7-10-99, Hobbs determined; Species: *carinirostris*, 8 ♂♂ I, 6 ♀♀.

USNM 23962 (Type specimen) Gandy Cr. at Osceola, W. P. Hay determined; U.S. Fish Comm., 7–12–99; Species: Type *carinirostris*, 1 ♂ I, 2 ♂♂ II, 17 ♀♀.

USNM 23963 Gandy Cr. at Osceola, Hobbs determined 1954, 7–12–99; Species: *carinirostris*, 20 specimens.

USNM 23973 Glady Fork at Seneca Rt. crossing. Hobbs determined 1954, 9–1–99; Species: *carinrostris*, 4 ♂♂ I, 2 ♂♂ II, 6 ♀♀.

USNM 23974 Laurel Fork of Cheat R. near Seneca R. crossing. Faxon determined, 7–31–99; Species: *carinirostris*, 1 specimen.

USNM 23981 Cheat R. at Raines (Jenningston now) listed as *C. b. bartoni* 9–2–99; changed by H. Hobbs 1–31–54; Species: *carinirostris*, 2 ♂♂ II, 2 ♂♂ imm., 3 ♀♀ imm.

USNM 28606 Cheat R. near Pike Hwy, Faxon determined 7–25–99; H. Hobbs changed 1954; Species: *carinirostris*, 2 ♂ ♂ I, 1 ♀.

USNM 28608 E. Fork Glady Cr. 7–10–99 checked by Hobbs 1954; Species: *carinirostris*, 5 ♂♂ I, 7 ♀♀.

USNM 88495 Three spring run Trib. to Glady Fork and Cheat R., 7–16–34, E. P. Creaser, Acc. 130968; Species: *carinirostris*, 3 ♂♂ II, 1 ♀.

West Virginia, Tucker County

501 Dry Fork 1.2 mi N of Jenningston Co. Rt. 35/15, 6–12–56; Bottom bedrock, boulders, pools of sand, algae; Temp, air 66, water 65; Flow 25 cfs; Depth 4′; Width 120′; Species: *bartoni*, 1 ♀; *orconectes*, 1 ♂ II, 4 ♀♀.

502* Dry Fork 1 mi NW Jenningston Rt. 35/15, 6–12–56; Bottom bedrock, sand and algae; Temp, air 65, water 58; Flow 25 cfs; Depth 6′; Width 120′.

509* Red Creek E of Laneville on USFS Rt. 19, 6–13–56; Bottom boulder; Temp, air 80, water 62; Flow 30 cfs; Depth 2′; Width 15′.

510 Mill Creek 1 mi W of Rt. 32, less than 1 mi W Cosner School on Co. Rt. 35, 6–13–56; Bottom mud and *chara*; Temp, air 82, water 70; Flow 5 cfs; Depth 3′; Width 10′; Species: *orconectes*, 21 ♂♂ I, 4 ♀♀ in Berry.

766 Mill Creek 1 mi W Cosner School 10 mi S of Davis, 10–14–56; Bottom mud and *chara*; Temp, air 65, water 60; Flow 0 cfs; Depth 3′; Width 10′; Species: *orconectes*, 3 ♀♀.

511 Blackwater R. on Rt. 32, 10 mi S Davis, 1.7 mi N of Cosner School, 6–13–56; Bottom mud, clay and *Vallisneria*; Temp, air 69, water 71; Flow 5 cfs; Depth 5′; Width 15′; Species: *orconectes*, 15 ♂♂ I.

512 North Branch Blackwater R. at Cortland Co. Rt. 35/18, 6–13–56; Bottom mud, rock; Temp, air 71, water 68; Flow 10 cfs; Depth 2′; Width 20′; Species: *bartoni*, 1 ♀; *orconectes*, 3 ♂♂ I, 5 ♀♀.

513 Sand Run on Harpers' Property NE of Cortland on Co. Rt. 37, 6–13–56; Bottom rock, rubble; Temp, air 67, water 67; Flow 5 cfs; Depth 2′; Width 10′; Species: *bartoni*, 4 ♂♂ I, 6 ♀♀; *orconectes*, 2 ♀♀.

514 Blackwater R. E of Cortland ½ mi on Co. Rt. 35/18; 6–13–56; Bottom rock and bedrock; Temp, air 67, water 67; Flow 10 cfs; Depth 2′; Width 20′; Species: *bartoni*, 1 ♂ I, 1 ♀; *orconectes*, 10 ♂♂ II, 1 ♀.

515 Blackwater R. I, 1 mi E of Bearden Knob 5 mi SE of Davis, 6–14–56; Bottom mud, sand; Temp, air 74, water 66; Flow 30 cfs; Depth 5′; Width 30′; Species: *orconectes*, 4 ♂♂ I 10 ♀♀.

516 Blackwater R. II, 1 mi E of Bearden Knob near Gas well C. & S., 6–14–56; Bottom mud, sand; Temp, air 65, water 61; Flow 25 cfs; Depth 4′; Width 20′; Species: *bartoni*, 3 ♂♂ I, 1 ♂ II, 4 ♀♀.

517 Glade Run near Little Blackwater R. in Canaan Valley, 6–14–56; Bottom sand, mud and *Vallisneria*; Temp, air 84, water 75; Flow 5 cfs; Depth 5′; width 10′; Species: *orconectes*, 10 ♀♀ in berry.

518* Little Blackwater Cr. E of jct with Blackwater R. 1.5 mi E of Davis, 6–14–56; Bottom mud, Temp, air 67, water 73; Flow 15 cfs; Depth 4′; Width 10′.

519* Red Run at first crossing of Rt. 13 USFS from Canaan Heights, east, 6-15-56; Bottom sand, rubble; Temp, air 70, water 58; Flow 15 cfs; Depth 2′; Width 15′.
520 Red Run at jct with USFS Rts. 13 and 13a, 6–15–56; Bottom rock, boulder; Temp, air 76, water 57; Flow 20 cfs; Depth 1½′; Width 15′; Species: *bartoni*, 5 ♂♂ I, 1 ♂ II, 8 ♀♀.
521 Yellow Cr. Trib. to Blackwater R. 2½ mi E of Davis on Pvt. Road, 6–16–56; Bottom sand, gravel and algae; Temp, air 79, water 67; Flow 5 cfs; Depth 1′; Width 10′; Species: *bartoni*, 2 ♂♂ I, 4 ♀♀.
522 Blackwater R. W of Yellow Cr. entry in dam area ¼ mi E of Davis, 6–16–56; Bottom rock, rubble; Temp, air 79, water 67; Flow 10 cfs; Depth 2′; Width 30′; Species: *bartoni*, 1 ♀; *orconectes*, 4 ♂♂ II, 3 ♀♀.
523 Devils' Run 1 mi S of Davis on US 32, 6–16–56; Bottom sand, boulders and algae; Temp, air 72, water 67; Flow 5 cfs; Depth 6′; Width 10′; Species: *bartoni*, 14 ♂♂ I, 14 ♀♀.
524 Blackwater R. at Davis So. City Limits, Rt. 32, 6–16–56; Bottom sand, rock and boulder; Temp, air 72, water 72; Flow 5 cfs; Depth 3′; Width 75′; Species: *orconectes*, 1 ♂ I.
525 North Fork Blackwater R. at Thomas on N Shore of City Park, 6–26–56; Bottom mud, snags, branches; Temp, air 69, water 65; Flow 5 cfs; Depth 18′; Width 125′; On North shore only. Species: *bartoni*, 1 ♂ I, 2 ♀♀; *orconectes*, 2 ♀♀.
526 No. 9 Run at Jct. of Rt. 24 and 90, 1 mi NE of Thomas, 6–26–56; Bottom mud, gravel; Temp, air 70, water 69; Flow 5 cfs; Depth 1′; Width 10′; Species: *orconectes*, 15 ♂♂ II, 9 ♀♀.
767 No. 9 Run at Jct. of Rt. 24 and 90, 1 mi NE of Thomas, 10–14–56; Bottom mud, gravel; Temp, air 65, water 60; Flow 10 cfs; Depth 1′; Width 10′; Species: *orconectes*, 5 ♂♂ II, 5 ♀♀.
527 North Fork Blackwater at William on Rt. 24, first bridge, 6–26–56; Bottom sand, rubble and *Vallisneria*; Temp, air 69, water 59; Flow 5 cfs; Depth 2′; Width 10′; Species: *bartoni*, 3 ♂♂ I; *orconectes*, 1 ♂ I, 14 ♀♀.
528* North Fork Blackwater 1.6 mi N of Thomas near Sand Run RR sign and W of Rt. 32, 6–26–56; Bottom mud, debris; Temp, air 72, water 61; Flow 5 cfs; Depth 6′; Width 30′.
529* Big Run ½ mi S of Benbush on Parsons-Thomas Rd. 72, 1½ mi NW of Thomas, 6–26–56; Bottom rubble, sand, coal washings; Temp, air 72, water 60; Flow 10 cfs; Depth 1′; Width 10′; Mine activities nearby.
530* North Fork Blackwater R. at So. City Limits of Thomas, 6–26–56; Bottom boulder and algae; Temp, air 73, water 62; Flow 45 cfs; Depth 2′; Width 20′.
531* North Fork Blackwater R. 1 mi SW of Thomas, ¾ mi NE Douglas at Coketon, 6–26–56; Bottom boulder; Temp, air 83, water 65; Flow 40 cfs; Depth 2′; Width 20′.
532 Pendelton Cr. midway between Davis and Thomas on W. Va. 32, 6–26–56; Bottom sand, rubble mud and *Vallisneria*; Temp, air 83, water 70; Flow 5 cfs; Depth 3′; Width 15′; Species: *bartoni*, 4 ♂♂ I, 2 ♀♀.
533* Blackwater R. 800′ above falls and downstream of new ski lodge bridge, 6–26–56; Bottom boulder; Temp, air 79, water 70; Flow 60 cfs; Depth 2′; Width 40′.
534 Beaver Cr. near Gatzmer Mine 6.5 mi NE Davis on Private Rd. 0.5 mi N of Davis, 6–27–56; Bottom sand and rubble; Temp, air 67, water 67; Flow 5 cfs; Depth 5′; Width 15′; Water red from strip mine; Species: *bartoni*, 10 ♂♂ I, 7 ♀♀.
535 Beaver Cr. just E of Davis City Limits East on W. Va. 32, 6–26–56; Bottom rock and sand; Temp, air 79, water 70; Flow 10 cfs; Depth 5′; Width 30′; Species: *bartoni*, 1 ♀.
536* Beaver Cr. 0.6 mi W of Coll. 534, 6–27–56; Bottom rock and sand; Temp, air 67, water 67; Flow 5 cfs; Depth 1′; Width 10′.
537 Beaver Cr. 5 mi E of Davis on Pvt. Rd., 6–27–56; Bottom rock, sand, algae in eddies; Temp, air 67, water 73; Flow 10 cfs; Depth 1′; Width 10′; Species; *bartoni*, 2 ♂♂ I, 2 ♀♀.
538 Big Run 0.2 mi NW Red Creek W. Va. on Rt. W. Va. 72 to Hendricks, 6–27–56; Bottom rock and rubble; Temp, air 69, water 64; Flow 15 cfs; Depth 3′; Width 10′; Species: *bartoni*, 16 ♂♂ I, 1 ♂ II, 8 ♀♀.
539 Big Run W of first bridge SW of Rt. 72, 6–27–56; Bottom bedrock; Temp, air 69, water 64; Flow 60 cfs; Depth 6′; Width 15′; Species: *bartoni*, 8 ♂♂ I, 5 ♀♀.
540* Dry Fork at jct to Laurel Creek at Jenningston, 6–28–56; Bottom boulder, sand; Temp, air 69, water 65; Flow 30 cfs; Depth 18; Width 75′.

541 Dry Fork South of Bridge and at Jenningston, W. Va. Co. Rt. 35/15, 6–28–56; Bottom Bedrock, sand, boulder and algae; Temp, air 64, water 66; Flow 25 cfs; Depth 6′; Width 75′; Species: *bartoni*, 1 ♂ II, *orconectes*, 1 ♀.

542* Laurel Cr. No. of jct with Dry Fork at Jenningston, 6–28–56; Bottom bedrock; Temp, air 64, water 60; Flow 60 cfs; Depth 2′; Width 60′.

543* Dry Fork at Jenningston Bridge in Deep Hole S of Bridge on Co. Rt. 35, 6–29–56; Bottom boulder, bedrock; Temp, air 68; water 60; Flow 30 cfs; Depth 15′; Width 200′.

544* Glady Fork W of Gladwin on Rt. W. Va. 26, 6–29–56; Bottom bedrock, boulder; Temp, air 68, water 63; Flow 40 cfs; Depth 2′; Width 60′.

545 Mill Run ¾ mi NW Elk on Rt. 72, 6–29–56; Bottom boulder, rubble and sand; Temp, air 73, water 60; Flow 15 cfs; Depth 1′; Width 10′; Species: *bartoni*, 7 ♂♂ I, 7 ♀♀.

546* Red Run 3 mi SE Hendricks on Rt. 72, 6–29–56; Bottom bedrock and some filamentous algae; Temp, air 73, water 61; Flow 15 cfs; Depth 1′; Width 25′.

553 Pleasant Run at Pleasant River, W. Va. 3 mi S Porterwood on Rt. 39 and 47, 7–2–56; Bottom bedrock, rock rubble, algae; Temp, air 79, water 69; Flow 10 cfs; Depth ½′; Width 10′; Species: *bartoni*, 3 ♂♂ I, 6 ♀♀.

554 Shavers Fork at jct with Pleasant Run 3 mi SW Parsons Rt. 39/47, 7–2–56; Bottom bedrock and boulder; Temp, air 74, water 76; Flow 30 cfs; Depth 3′; Width 150′; Species: *bartoni*, 1 ♂ I.

555 Haddix Run at Moore on US 219, 7–2–56; Bottom rock, rubble, clay, algae; Temp, air 74, water 73; Flow 5 cfs; Depth 1′; Width 10′; Species: *bartoni*, 14 ♂♂ I, 15 ♀♀.

556 Haddix Run at Porterwood US 219 and Co. Rt. 39, 7–2–56; Bottom rubble and sand; Temp, air 74, water 80; Flow 10 cfs; Depth 1′; Width 15′; Species: *bartoni*, 2 ♀♀; *orconectes*, 1 ♀.

557* Shavers Fork at Porterwood on Co. Rt. 39, 7–3–56; Bottom boulders, rock, gravel, sand, mud; Temp, air 74, water 76; Flow 30 cfs; Depth 4′; Width 200′.

558* Otter Cr. entry W of Dry Fork 2.5 mi SE Hendricks and W. Va. 72, 7–3–56; Bottom boulder; Temp, air 84, water 70; Flow 10 cfs; Depth 2′; Width 20′.

559* Dry Fork N of Otter Cr. and 50′ W of W. Va. 72, 7–4–56; Bottom huge round boulder; Temp, air 68, water 73; Flow 20 cfs; Depth 6′; Width 120′.

560* Dry Fork at Hambleton E City Limit on W. Va. 72, 7–4–56; Bottom boulders, rock and filamentous algae; Temp, air 73, water 73; Flow 25 cfs; Depth 3′; Width 200′.

561* Blackwater River at Hendricks on W. Va. 72, 7–4–56; Bottom boulders; Temp, air 82, water 75; Flow 80 cfs; Depth 2′; Width 50′.

562* Black Fork at SE Parsons City Limit, 7–4–56; Bottom rock and boulders; Temp, air 79, water 75; Flow 30 cfs; Depth 1½′; Width 250′; Water black colored.

563 Shavers Fork at Parsons S City Limit opposite fallen brick cylinders and VFW Pond, 7–4–56; Bottom mud, rock, sand and *Vallisneria* in eddies; Temp, air 88, water 77; Flow 20 cfs; Depth 2′; Width 80′; Species: *orconectes*, 5 ♂♂ II, 16 ♀♀.

564* Cheat R. Holly Meadows, 1 mi S via farmers road Rt. 1, 7–5–56; Bottom mud, bedrock, boulders; Temp, air 85, water 79; Flow 50 cfs; Depth 12′; Width 200′.

565 Walt Cr. Trib. to Cheat R. 200′ from mouth in small pool on Horseshoe-Parsons Rt. 1, 7–5–56; Bottom bedrock and mud; Temp, air 82, water 77; Flow 5 cfs; Depth ½′; Width 10′; Species: *bartoni*, 5 ♂♂ I, 5 ♀♀.

566 Mill Cr. 4.5 mi SE St. George on Co. Rt. 1, 7–6–56; Bottom bedrock, gravel; Temp, air 71, water 64; Flow 20 cfs; Depth 2′; Width 10′; Species: *bartoni*, 5 ♂♂ I, 7 ♀♀.

567 Horseshoe Cr. 100 yds N of Shafer Co. Rt. 7/3, 7–6–56; Bottom rubble; Temp, air 70, water 66; Flow 5 cfs; Depth 1′; Width 10′; Species: *bartoni*, 4 ♂♂ I, 4 ♀♀.

568 Wolf Run SE of Shafer on Co. Rt. 7/5, 7–6–56; Bottom bedrock, rubble; Temp, air 70, water 65; Flow 10 cfs; Depth 1′; Width 10′; Species: *bartoni*, 2 ♂♂ I, 7 ♀♀.

569 Leadmine Cr. 1 mi N of Leadmine on Rt. 7, 7–6–56; Bottom rubble; Temp, air 70, water 64; Flow 10 cfs; Depth 2′; Width 15′; Species; *bartoni*, 6 ♂♂ I, 2 ♀♀.

570 Horseshoe Cr. at Leadmine on W. Va. 7, 7–6–56; Bottom bedrock and rubble; Temp, air 70, water 67; Flow 15 cfs; Depth 2′; Width 20′; Species: *bartoni*, 2 ♂♂ I, 1 ♀.

571 Hyle Run 1 mi SW of Leadmine on Location Rd. Rt. 9, 7–6–56; Bottom rubble; Temp, air 72, water 66; Flow 10 cfs; Depth 1′; Width 15′; Species: *bartoni*, 4 ♂♂ I, 5 ♀♀.

572 Maxwell Cr. Trib. to Horseshoe on Rt. 9 and 7 S of Leadmine, 7–6–56; Bottom rubble; Temp, air 72, water 64; Flow 20 cfs; Depth 2′; Width 15′; Species: *bartoni*, 9 ♂♂ I, 6 ♀♀.

573 Horseshoe Cr. above Drift Run and near School House on Co. Rt. 9, 7–6–56; Bottom rubble; Temp, air 72, water 68; Flow 20 cfs; Depth 2′; Width 70′; Species: *bartoni*, 3 ♂♂ I, 3 ♀♀.

574 Horsecamp Run 3 mi SE of St. George on Co. Rt. 1, 7–6–56; Bottom rubble; Temp, air 72, water 68; Flow 25 cfs; Depth 3′; Width 60′; Species: *bartoni*, 1 ♀.

575 Right Fork Clover Run SW of St. George 2½ mi Co. Rt. 15, 7–7–56; Bottom flatrock, rubble; Temp, air 64, water 64; Flow 5 cfs; Depth ½′; Width 10′; Species: *bartoni*, 5 ♂♂ I, 1 ♂ II, 2 ♀♀.

576 Indian Fork of Clover Run N of Harper School House and Co. Rt. 17/7, 7–7–56; Bottom flatrock; Temp, air 66, water 67; Flow 5 cfs; Depth ½′; Width 15′; Species: *bartoni*, 2 ♂♂ I, 3 ♀♀.

577 Left Fork Clover Run at Harper School on Co. Rt. 8, 7–7–56; Bottom rubble; Temp, air 72, water 67; Flow 10 cfs; Depth 2′; Width 20′; Species: *bartoni*, 4 ♀♀.

578 Left Fork Clover Run on Co. Rt. 21, 7–7–56; Bottom rubble; Temp, air 72, water 70; Flow 10 cfs; Depth 2′; Width 40′; Species: *bartoni*, 3 ♀♀.

579 Clover Run 2.5 mi SW of St. George Rt. 15/21, 7–7–56; Bottom bedrock, flatrock, rubble; Temp, air 77, water 71; Flow 10 cfs; Depth 2′; Width 30′; Species: *bartoni*, 1 ♂ I, 1 ♀.

580* Clover Run at W. Va. Rt. 72 N of St. George 100′ W of Cheat River, 7–7–56; Bottom rubble; Temp, air 75, water 72; Flow 10 cfs; Depth 1′; Width 50′.

581 Minear Run at Kellar Farm 1 mi NE St. George on Co. Rt. 12, 7–8–56; Bottom bedrock, flatrock; Temp, air 69, water 67; Flow 15 cfs; Depth 2′; Width 15′; Species: *bartoni*, 2 ♂♂ I, 8 ♀♀.

582* Minear Run at St. George on Co. Rt. 12, 7–8–56; Bottom, bedrock, flatrock; Temp, air 72, water 67; Flow 15 cfs; Depth 2′; Width 15′.

583 Bull Run 4 mi NW of St. George on W. Va. 72 and Co. Rt. 13, 7–8–56; Bottom flatrock; Temp, air 73, water 67; Flow 5 cfs; Depth 1′; Width 15′; Species: *bartoni*, 7 ♂♂ I, 11 ♀♀.

584 Licking Cr. near Macedonia Church and jct. Rt. Co. 11 and W. Va. 72, 7–8–56; Bottom rubble; Temp, air 72, water 68; Flow 5 cfs; Depth 1′; Width 15′; Species: *bartoni*, 2 ♂♂ I, 2 ♀♀.

591* Cheat R. at Holly Meadows just E of Co. Rt. 1, 7–12–56; Bottom boulder, rubble, Dianthera; Temp, air 80, water 68; Flow 30 cfs; Depth 2′; Width 130′.

592* Cheat R. 2 mi SE St. George on Co. Rt. 1, 7–12–56; Bottom boulder, rubble, sand bars, Dianthera; Temp, air 82, water 68; Flow 70 cfs; Depth 2′; Width 300′.

593* Cheat R. at St. George W City Limit and near jct of W. Va. 72, 7–12–56; Bottom mud, rock, boulder, Dianthera, Scurpus, Vallisneria; Temp, air 76, water 71; Flow 20 cfs; Depth 3′; Width 240′.

594* Cheat R. 500′ S of Bull Run entry near Co. Rt. 13 and W. Va. 72, 7–12–56; Bottom rock, rubble; Temp, air 80, water 73; Flow 15 cfs; Depth 2′; Width 250′.

595* Cheat R. 1 mi N Hannahsville School and 1 mi S Tucker-Preston Co. line, W. Va. 72 and Co. Rt. 3, 7–13–56; Bottom mud, sand, rock, Dianthera, newfar and chara in eddies; Temp, air 67, water 68; Flow 5 cfs; Depth 3′; Width 300′.

596* Cheat R. at Hannahsville 1 mi S Tucker-Preston Co. line on W. Va. 72, 10–14–56; Bottom rubble, sand, whole islands of Dianthera; Temp, air 66, water 69; Flow 30 cfs; Depth 2′; Width 300′.

USNM 23964 No. Fork of Blackwater at Courtland, 8–25–99; Hobbs determined 1954; Species: *carinirostris*, 10 ♂♂ I, 7 ♂♂ II, 6 ♂♂ imm., 11 ♀♀. 4 ♀♀ imm.

USNM 23965 Blackwater R. 2 mi above Courtland, 8–25–99; Faxon determined, Hobbs checked 1954; Species: *carinirostris*, 21 ♂♂ II, 250 ♀♀.

USNM 23966 Blackwater R. 2 mi above Courtland, 8–25–99; Hobbs checked 1954; Species: *carinirostris*, 14 ♂♂ I, 12 ♂♂ II, 46 ♀♀.

USNM 23970 Red Cr. at jct with Dry Fork of Cheat R., 8–26–99; Hay determined, Hobbs checked 1954; Species: *carinirostris*, 1 ♂ I, 2 ♀♀.

Unknown County (Randolph or Pocahontas)

USNM 23969 Shavers Fork, 7–9–99; Hay determined, Hobbs checked 1954; Species; *carnirostris*, 3 ♂♂ I, 1 ♂ II, 1 ♂ imm., 7 ♀♀.

Summary

Only two species of crayfish were currently encountered in the Cheat River watershed of West Virginia and Pennsylvania as tributary to the Monongahela-Ohio River systems. These were 1155 specimens of *Cambarus bartoni bartoni* and 269 specimens of *Orconectes obscurus*. Recorded specimens exist for two other species, *Cambarus bartoni carinirostris* and *Cambarus carolinus carolinus*. However, either as a result of their burrowing habits (*C. carolinus*) or perhaps possible recent extirpation (*C. b. carinirostris*), these were not captured within the streams sampled. A total of 233 collections was made throughout the Cheat watershed during 1956. Of these, 153 collections, 66.0 percent, contained samples of crayfish whereas 80 samples (34 percent) were void of crayfish. In 138 samples, *Cambarus b. bartoni* occurred alone. *Orconectes obscurus* occurred alone in 34 collections while in only 19 collections did the two species occur together. Generally, *Cambarus b. bartoni* was the most widely distributed species. *Orconectes obscurus* occupied the larger foothill streams and was replaced at higher elevations or in faster flowing streams by *C. b. bartoni*. Both species were conspicuously absent from the main central portion of the watershed.

Apparent disagreements exist between various crayfish specialists regarding the identity and/or presence of *C. b. carinirostris* in the Blackwater River portion of the system. Further study will be necessary to delineate the subspecies *carinirostris* from *bartoni*.

Acknowledgments

Thanks are due the following people or agencies who contributed to make the original survey possible and who helped expedite completion of this manuscript: West Pennsylvania Power Company, Monongahela Power Company, Isaac Walton League of America Morgantown Chapter and Mr. Ward Christopher of the Consolidated Coal Company of Morgantown, West Virginia, all of whom helped to establish research grants subsequent to which this study was possible; Drs. Earl Core and Paul Price of West Virginia University who were instrumental in establishing the grants; Dr. Horton Hobbs, University of Virginia for aid with identification of some forms of specimens cited herein as well as for review of the manuscript; Dr. Fenner Chase, Curator Division Marine Invertebrates, U. S. National Museum, for access and loan of specimens of *C. b. carinirostris:* Messrs. F. Beaven, D. Cargo, J. Longwell and J. Muncy of Chesapeake Biological Laboratory for review and criticism of the manuscript; Mrs. Gloria Lankford who expedited the laborious task of converting much hand scrawled data into the form herein.

LITERATURE CITED

Faxon, W. 1914. Notes on the crayfishes in the U.S.N.M. and the Museum of Comparative Zoology. Mem. Mus. Comp. Zool. 40: 351–427, pl. 1–13.

Hay, W. P. 1899. Synopsis of North American Invertebrates. VI. The Astacedae of North America. Amer. Nat. 33: 957–966.

——. 1902. On the proper application of the name *Cambarus carolinus* Erickson. Proc. Biol. Soc. Wash. 15, p. 38.

Hobbs, H. H. 1942. A generic revision of the Cambarinae. Amer. Midl. Nat. 28: 334–357.

Newcombe, C. L. 1924. The crayfishes of West Virginia. Ohio Jour. Sci. 19: 267–288.

Ortmann, A. E. 1905. The material affinities of the species of the genus *Cambarus* and their dispersal over the U.S. Proc. Amer. Phil. Soc. 44: 91–136, 1 pl.

——. 1906. The crayfishes of the state of Pennsylvania. Mem. Carnegie Mus. 2: 343–521.

——. 1913. The Alleghenian Divide and its influence upon the freshwater fauna. Proc. Amer. Philos. Soc. 52: 287–390.

——. 1931. Crawfishes of the Southern Appalachians and the Cumberland Plateau. Ann. Carnegie Mus. 20: 61–160.

Turner, C. E. 1926. The crayfishes of Ohio. Ohio Biol. Survey. Bull. 13, Vol. 3, No. 3.

Williamson, E. B. 1901. Crayfish of Allegheny County, Pennsylvania. Ann. Carnegie Mus. Vol. 1: 1–13.

THE FAMILY CRUCIFERAE IN THE GREAT BLACK SWAMP REGION OF OHIO*

NATHAN WILLIAM EASTERLY

Department of Biology, Bowling Green State University, Bowling Green, Ohio

The phytogeographic region of Ohio known as the Great Black Swamp comprizes that area drained by the Maumee River. As outlined by Schaffner (1932), the counties involved include Lucas, Wood, Henry, Sandusky, Hancock, Putnam, Van Wert, Paulding, Defiance, Williams, and Fulton. Following the advances of modern agriculture, this region has been widely cultivated and natural habitats are confined to stream banks, state forest or park areas and a few relatively undisturbed wooded lots. Other farm woodlands have been grazed. Disturbed habitats such as roadsides, railroad banks, moist pastures, cultivated fields and drainage ditch banks provide suitable habitats for members of the mustard family.

The family Cruciferae represents one of the larger segments of the flora of the Great Black Swamp. The four-parted, tetradynamous flowers are readily identified. However, identification of the genera and species proves more difficult. It is essential that the plants are collected in mature fruit, preferably with flowers present at the apex of the inflorescence.

While most of our mustards occupy weedy habitats, genera such as *Dentaria* and *Cardamine* are found in moist rich woods as part of our spring flora. Other genera such as *Hesperis* and *Nasturtium* have been cultivated and established themselves in the wild. Many of the mustards have been introduced from Europe and have established themselves as weeds along roadsides and in waste places.

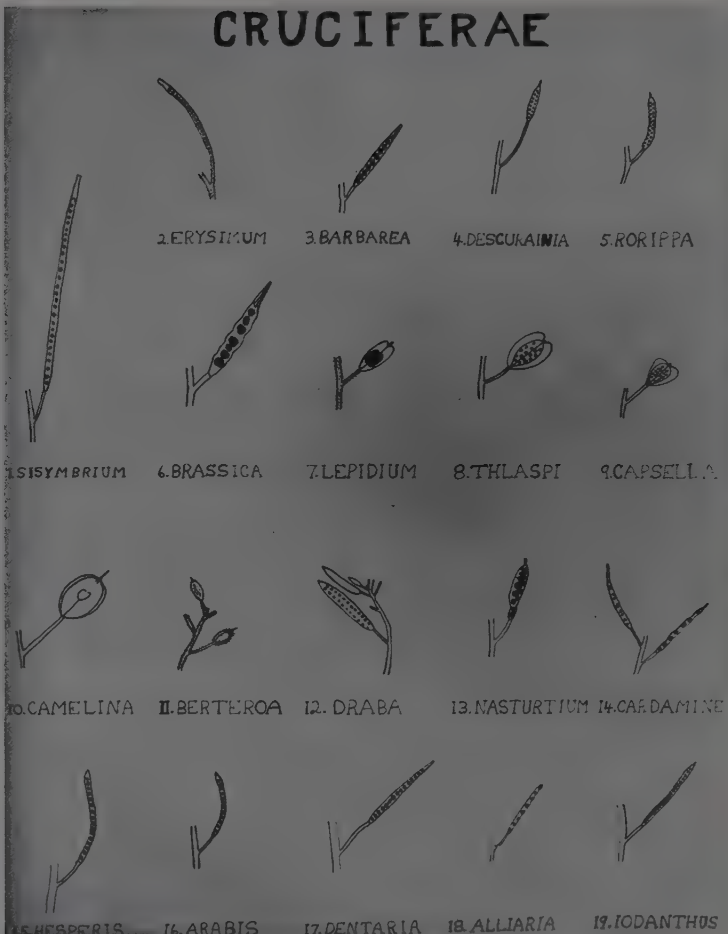
E. L. Moseley (1928) lists 14 species from the Oak Openings area. J. H. Schaffner (1932) reports 39 species from the counties of northwest Ohio. The present paper provides a guide for 33 species dispersed among 19 genera. Nomenclature follows that of H. A. Gleason (1952).

KEY TO GENERA

A. Fruit not more than 5 times as long as wide, a silicle.
- B. Fruit flattened.
  - C. Locule one seeded .... 7. *Lepidium*
  - CC. Locule more than one seeded.
    - D. Fruit obcordate, triangular, narrowly winged at summit .. 9. *Capsella*
    - DD. Fruit orbicular or broadly elliptic with conspicuous wing encircling fruit .... 8. *Thlaspi*
- BB. Fruit not flattened.
  - E. Fruit elongated, at least twice as long as wide.
    - F. Pubescence of both simple and branched hairs, leaves mostly basal 12. *Draba*
    - FF. Pubescence of simple hairs, or none, stems leafy .... 5. *Rorippa*
  - EE. Fruit obovoid or elliptic
    - G. Flowers yellow, petals not cleft, seeds not winged .... 10. *Camelina*
    - GG. Flowers white, petals deeply cleft, seeds winged .... 11. *Berteroa*

AA. Fruit more than 5 times as long as wide, a silique.
- H. Flowers yellow.
  - I. Fruit divided transversely into a lower, dehiscent, seed-bearing unit and an upper, indehiscent beak, 8–15 mm long .... 6. *Brassica*

*Research supported by a grant from The Ohio Academy of Science.



EXPLANATION OF FIGURES IN PLATE

1. *Sisymbrium altissimum* L.
2. *Erysimum repandum* L.
3. *Barbarea vulgaris* R. Br.
4. *Descurainia pinnata* (Walt.) Britt. var. *brachycarpa* (Richards) Fern.
5. *Rorippa sylvestris* (L.) Besser.
6. *Brassica kaber* (DC.) L. Wheeler
7. *Lepidium campestre* (L.) R. Br.
8. *Thlaspi arvense* L.
9. *Capsella bursa-pastoris* (L.) Medic.
10. *Camelina microcarpa* Andrz.
11. *Berteroa incana* (L.) DC.
12. *Draba reptans* (Lam.) Fern.
13. *Nasturtium officinale* R. Br.
14. *Cardamine bulbosa* (Schreb.) BSP
15. *Hesperis matronalis* L.
16. *Arabis lyrata* L.
17. *Dentaria laciniata* Muhl.
18. *Alliaria officinalis* Andrz.
19. *Iodanthus pinnatifidus* (Michx.) Steud.

II. Fruit not so divided.
J. Seeds in two rows in each valve of the fruit.
K. Stems glabrous or pubescent with simple hairs, raceme not glandular....................................5. *Rorippa*
KK. Stem pubescent with simple and branched hairs, raceme with short stipitate glands........................4. *Descurainia*
JJ. Seeds in one row in each valve of the fruit.
L. Stems pubescent with branched or stellate hairs...2. *Erysimum*
LL. Stems pubescent with simple hairs or glabrous.
M. Cauline leaves clasping stem, basal leaves pinnatifid with large terminal lobe...................3. *Barbarea*
MM. Cauline leaves not clasping stem, basal leaves pinnatifid but with no large terminal lobe.....1. *Sisymbrium*
HH. Flowers white, pink or purple.
N. Leaves palmately divided or palmately compound.............17. *Dentaria*
NN. Leaves not palmately divided or palmately compound.
O. Cauline leaves simple.
P. Cauline leaves deltoid, 3–6 cm long and wide, coarsely toothed.......................................18. *Alliaria*
PP. Cauline leaves not as above.
Q. Valves of fruit nerveless and roll spirally at dehiscence 14. *Cardamine*
QQ. Valves nerved, do not roll spirally at dehiscence.
R. Petals with a claw, flowers pale violet or purple, valve of fruit with inconspicuous midnerve.
S. Stems with both simple and branched hairs........................15. *Hesperis*
SS. Stems with simple hairs or glabrous.... 19. *Iodanthus*
RR. Petals without a claw, flowers usually white, valve of fruit with conspicuous midnerve.... 16. *Arabis*
OO. Cauline leaves compound.
T. Petals bearing a claw, seeds wingless..........13. *Nasturtium*
TT. Petals not bearing a claw, seeds narrowly winged..14. *Cardamine*

1. *Sisymbrium* L.

Annual plants, 3–10 dm tall. Stem glabrous or pilose with simple hairs. Leaves deeply pinnatifid, segments linear, lanceolate or ovate. Flowers yellow. Fruit elongate, tipped by minute, persistent style with prominent midnerve and two lateral nerves on each valve.

Plants introduced from Europe and inhabit fields, roadsides and waste places.

A. Fruits awl-shaped, appressed, 10–15 mm long; leaf segments usually ovate............ *S. officinale* (L.) Scop. Hedge Mustard
AA. Fruits linear, widely divergent, 5–10 cm long; leaf segments linear to lanceolate........ *S. altissimum* L. Tumbling Mustard

2. *Erysimum* L.

Annual or perennial plants, 2–10 dm tall. Stem pubescent with branched hairs. Cauline leaves entire or minutely toothed, basal leaves similar or pinnatifid. Flowers yellow. Fruit elongate, pubescent, with prominent nerve on each valve.

Plants adventive along railroads or in waste places, introduced from Europe and Eurasia.

A. Fruits ascending, 15–20 mm long; basal and cauline leaves similar, linear or lanceolate, entire or remotely sinuate.....................*E. cheiranthoides* L. Wormseed Mustard
AA. Fruits divergent, 5–12 cm long; basal leaves pinnatifid, cauline leaves remotely sinuate-dentate..*E. repandum* L. Treacle Mustard

3. *Barbarea* R. Br.

Biennial plants, 2–8 dm tall. Stem glabrous or with few simple hairs. Basal leaves deeply pinnatifid with conspicuous terminal lobe, cauline leaves clasping and fewer lobed or merely toothed. Flowers yellow. Fruit elongate, minutely tipped, with prominent nerve and lateral veins on each valve.

Plants introduced from Europe and inhabit moist fields and ditches, often abundant in grain fields. Young basal leaves can be used for "greens."
B. vulgaris R. Br. Winter Cress.

4. *Descurainia* Webb. & Berth.

Annual or biennial plants, 2–7 dm tall. Stem glabrous or sparsely pubescent with branched hairs. Raceme with short glandular hairs. Basal leaves bipinnately compound or with deep pinnatifid segments, cauline leaves less divided. Flowers yellow or pale yellow. Fruits elongate, club-shaped, 8–10 mm long, 1–2 mm wide, with prominent nerve on each valve.

A native species inhabiting prairies, sandy areas and open woodland. Basal rosette of leaves usually absent at flowering time. The bipinnately compound leaves and glandular inflorescence are outstanding characteristics of this species. ***D. pinnata*** (Walt.) Britt. var. ***brachycarpa*** (Richards.) Fern.

Tansy Mustard.

5. *Rorippa* Scop.

Annual, biennial or perennial plants, 2–10 dm tall. Stem glabrous or pubescent with simple hairs. Leaves pinnatifid, basal leaves more deeply segmented. Flowers yellow. Fruit elongate or ovoid, with obscure midnerve on each valve.

Plants inhabiting wet soil, shores of rivers or streams and wet meadows.

A. Plant perennial from a rhizome, fruits commonly cylindric.....................
R. sylvestris (L.) Besser. Marsh Cress

AA. Plant annual or biennial from stout roots, fruits commonly ovoid..................
R. islandica (Oeder.) Borbas var. ***fernaldiana*** Butters & Abbe. Yellow Cress

6. *Brassica* L

Annual or biennial plants, 2–15 dm tall. Stem glabrous or sparsely hirsute. Basal leaves variously lobed, cauline leaves lobed, coarsely toothed or entire. Flowers yellow. Fruit elongate, with prominent beak; valves with prominent nerve or nerves.

Plants inhabit waste places, roadsides and fields, introduced from Europe.

A. Three conspicuous parallel nerves on each valve of the fruit.....................
B. kaber (DC.) L. Wheeler. Charlock.

AA. One conspicuous midnerve on valve of fruit, other nerves inconspicuous.

B. Upper cauline leaves sessile and clasping.................................
B. campestris L. (***B. rapa*** L.) Field Mustard

BB. Upper cauline leaves not clasping, usually petiolate........................
B. nigra (L.) Koch. Black Mustard

7. *Lepidium* L.

Annual, biennial or perennial plants, 2–5 dm tall. Stem minutely to densely pubescent with short, simple hairs. Basal leaves sparsely lobed to pinnatifid, cauline leaves entire to dentate. Flowers white. Fruit short, flattened at right angles to the septum, orbicular to ovate in outline.

Plants inhabit waste places, roadsides and fields. The first species has been introduced from Europe. All these species have become common weeds.

A. Cauline leaves sessile and clasping, stem densely pubescent with short, simple hairs
L. campestre (L.) R. Br. Field Cress

AA. Cauline leaves sessile but not clasping; stem minutely pubescent.

B. Petals same length or longer than sepals..........***L. virginicum*** L. Pepper Grass

BB. Petals shorter than sepals or absent..... ***L. densiflorum*** Schrader. Pepper Grass

8. *Thlaspi* L.

Annual plants, 1–5 dm tall. Stem glabrous. Basal and cauline leaves similar, the latter clasping stem. Flowers white in our species. Fruit oribcular, flattened, and deeply notched at the apex, conspicuously winged.

Plants introduced from Europe and inhabit roadsides and waste places. Similar to *Lepidium*, but can be separated easily by the number of seeds in each locule. *T. arvense* L. Penny Cress.

9. *Capsella* Medic.

Annual or biennial plants, 1–6 dm tall. Stem pubescent with stellate hairs. Basal leaves pinnately lobed, forming rosette. Cauline leaves entire or denticulate, sessile and clasping stem. Flower white. Fruit flat, triangular, notched at the apex.

Plants have become cosmopolitan, inhabiting waste places, roadsides and lawns; introduced from Europe.

C. bursa-pastoris (L.) Medic. Shepherd's Purse.

10. *Camelina* Crantz.

Annual plants, 3–7 dm tall. Stems glabrous, sparsely pubescent or more densely pubescent with both simple and branched hairs. Basal leaves short, petiolate. Cauline leaves sessile and clasping. Flowers yellow. Fruit obovoid, 7–10 mm long, 5–7 mm wide, with persistent style at apex.

Plants inhabiting waste places, railroad banks and fields, introduced from Europe. Similar to *Berteroa*, but can be separated by the pubescence or flower color.

A. Stem glabrous or pubescent with closely appressed branched hairs, fruit 6–10 mm long
C. sativa (L.) Crantz. False Flax

AA. Stem pubescent with both simple and branched hairs, fruit 4–6 mm long...........
C. microcarpa (L.) Crantz. False Flax

11. *Berteroa* DC.

Annual plants, 2–7 dm tall. Stems canescent, with short, stellate hairs. Leaves entire, oblanceolate, sessile, not clasping. Flowers white. Fruits elliptic, 5–8 mm long, 3–4 mm wide, with persistent style at apex.

Plants introduced from Europe, inhabit waste places and fields.

B. incana (L.) DC. Hoary Alyssum.

12. *Draba* L.

Annual plants, 5–15 cm tall. Stem sparsely pubescent with simple hairs. Leaves mostly basal, obovate, pubescent with simple hairs on upper surface, stellate hairs beneath. Flowers white in our species. Fruit elongate, 1–2 cm long.

Plants of sandy soil. Moseley (1928) reports that these plants are more common where thin soil overlies limestone.

D. reptans (Lam.) Fern. Whitlow Grass.

13. *Nasturtium* R. Br.

Aquatic herbs. Stems glabrous and prostrate, many nodes producing roots. Leaves pinnately compound with orbicular segments, terminal segments usually larger. Flowers white. Fruit elongate, slender, 10–25 mm long.

Plants escaped cultivation and now inhabiting slow streams and wet ditches. Originally cultivated for salad, introduced from Europe.

N. officinale R. Br. Water Cress.

14. *Cardamine* L.

Annuals, biennials or perennial plants, 2–6 dm tall. Stems glabrous or sparsely pubescent with simple hairs. Leaves simple or compound. Flowers white or pinkish purple. Fruit elongate, narrow, 15–25 mm long.

Plants of our spring flora, inhabiting moist or wet woods.

A. Leaves compound, leaflets decurrent along the rachis, terminal leaflet much larger, obovate, roots fibrous..........................*C. pensylvanica* Muhl. Bitter Cress

AA. Leaves simple, basal leaves orbicular with long petiole; cauline leaves ovate to lanceolate, commonly toothed; roots tuberous.

B. Flowers white, cauline leaves 5–10 in number............................
C. bulbosa (Schreb.) BSP. Bitter Cress

BB. Flowers pink-purple, cauline leaves 3–5 in number........................
C. douglasii (Torr.) Britt. Purple Bitter Cress

15. *Hesperis* L.

Biennial or perennial plants, 5–10 dm tall. Stems pubescent with simple and branched hairs. Leaves sessile or short petiolate, lanceolate or oblong, with simple hairs on upper surface, branched hairs beneath. Flowers commonly purple, varying to white. Fruit elongate, slender, with conspicuous swelling at apex of pedicel when fruits are young.

Plants escaped cultivation, inhabit moist meadows, river banks and moist open woods, introduced from Europe.

H. matronalis L. Dame's Rocket.

16. *Arabis* L.

Annual, biennial or perennial plants, 1–10 dm tall. Stems pubescent with simple or branched hairs, commonly at the base of the stem. Basal leaves entire to pinnately lobed; cauline leaves smaller, sessile. Flowers white in our species. Fruit elongate, many times longer than wide.

Plants of fields or open woods.

A. Pedicels widely spreading at maturity, fruits slightly to strongly decurved.
  B. Basal leaves stellate pubescent on both surfaces.......................... *A. divaricarpa* A. Nels. Rock Cress
  BB. Basal leaves glabrous or minutely pubescent with straight hairs.
    C. Fruits 3–4 mm wide, slightly decurved at maturity, cauline leaves sessile, no sagitate base............................*A. canadensis* L. Sickle Pod
    CC. Fruits 1–2 mm wide, strongly decurved at maturity, cauline leaves sessile, with sagittate base.................*A. laevigata* (Muhl.) Poir. Rock Cress
AA. Pedicels ascending or appressed at maturity.
  D. Cauline leaves sessile, linear to spatulate, plant 1–4 dm tall; seeds in one row in each valve of the fruit.......................*A. lyrata* L. Lyre-leaf Rock Cress
  DD. Cauline leaves commonly auriculate, lanceolate to narrowly oblong, plant 3–9 dm tall seeds in two rows in each valve of the fruit. . *A. drummondi* Gray. Rock Cress

17. *Dentaria* L.

Perennial plants with rhizomes, 2–4 dm tall. Stem pubescent above with simple hairs. Leaves all similar, in whorls of three, palmately dissected, segments entire or toothed. Flowers white. Fruit elongate, tapering to a long beak.

Plants of our spring flora, inhabiting moist woods. *D. laciniata* Muhl. Toothwort.

18. *Alliaria* Scop.

Biennial or perennial herbs, 4–10 dm tall. Stem glabrous or sparsely pubescent with simple hairs. Cauline leaves simple, deltoid, coarsely toothed. Flowers white. Fruit elongate, narrow, with conspicuous midnerve on each valve.

Plants introduced from Europe, inhabiting moist, shady places. Crushed leaves have the odor of garlic.

A. officinalis Andrz. Garlic Mustard.

19. *Iodanthus* T. & G.

Perennial plants, 6–10 dm tall. Stem glabrous or pubescent with simple hairs. Leaves sessile, lanceolate or elliptic, basal ones commonly pinnatifid at the base of the blade. Flowers pale purple to white. Fruit linear, valve with inconspicuous midnerve.

Plants inhabit alluvial woods. Similar to *Hesperis*, but the plants are usually glabrous and possess only simple hairs when pubescent.

I. pinnatifidus (Michx.) Steud. Purple Rocket.

LITERATURE CITED

Deam, C. C. 1940. Flora of Indiana. Dept. Conservation, Div. of Forestry, Indianapolis. 1236 pp.

Fernald, M. L. 1950. Gray's Manual of Botany. 8th ed. American Book Company, New York. 1632 pp.

Gleason, H. A. 1952. The New Britton and Brown Illustrated Flora of the Northeastern United States and Canada. 3 vols. New York Botanical Garden, New York. 1726 pp.

Jones, G. N. 1950. Flora of Illinois. 2nd ed. Amer. Midl. Nat. Monograph No. 5. 368 pp.

Moseley, E. L. 1928. Flora of the Oak Openings. Proc. Ohio Acad. Sci. 8: 82–134. Special paper No. 20.

Schaffner, J. H. 1932. Revised catalog of Ohio vascular plants. Ohio Biol. Surv. Bull. 5: 89–215.

BOOK REVIEWS

General Geology Laboratory Workbook. *Samuel P. Ellison, Jr.*, Editor. Harper & Brothers, Publishers, New York. 1958. x+285 pp. $3.75.

This newest member of Harper's Geoscience Series is a paperbound workbook that is somewhat more complete and elaborate than most workbooks for general geology. The book consists of 34 exercises, which differ considerably in style and in time required for proper accomplishment. Twenty-two are concerned with topics in physical geology: minerals and rocks, topographic map construction an interpretation, and physiographic analysis. Six deal with the classification of animals and plants. One, in six parts, consists of block diagrams, in the flat and with only part of the geology shown, which the student must cut out, fold and paste into a solid figure, and complete by diagramming the geology on the blank faces. Five exercises are planned for work with various geologic maps supplied in the laboratory. In addition, there are six diagrammatic geologic maps that may be employed in various ways, and sheets on which field trip reports may be made. Supplementary to the historical exercises are homework outline sheets for each geologic period, on which the student may summarize the salient features of each period in North America. On the back of each is an outline Map on (*sic*) Outcrops and Paleogeography. These outlines and maps should be very helpful to the student of historical geology, by permitting him to organize a wealth of detail in a small space for learning and for review.

Most of the exercises are designed for use with whatever topographic and geologic maps or other materials the instructor may wish to use. Suggested lists of such items are included with each exercise. All the exercises are flexible in that regard, which makes it unlikely that files of completed exercises will be gathered by students and copied from year to year. The study questions and lists of appropriate references that accompany most of the exercises are generally excellent. Each topic covered by an exercise or exercises is introduced by a brief treatment of the subject, as a reinforcement of lectures and text assignments. All the pages are perforated for ready removal for submission to the instructor.

Although this workbook is a versatile and effective teaching aid, and perhaps the best such available, it does have some unfortunate aspects. Fluorescent light is considered synonymous with black light (p. 5). In the study of regional stream topography, no clear distinction is made between landforms in arid and in humid regions. The term paternoster lakes is little used by present-day glacial geologists. Ice sheets surely are normally characteristic of high latitudes rather than high altitudes (p. 125). The study of shorelines and shoreline processes is built around the outmoded and misleading classification into emerging, submerging, neutral, and compound shorelines (p. 151–159). Some of the modes of expression in the descriptive paragraphs are hardly good examples for impressionable college students: e.g., p. 201, "The student will find historical geology fascinating and easy to learn if he takes time to organize himself on these summary outlines." Notwithstanding objections of this sort, this imaginative workbook is a good one, is reasonably priced, and merits the serious consideration of anyone responsible for college courses in elementary geology.

Malcolm P. Weiss

The Chemical Dynamics of Bone Mineral. *William F. Neuman* and *Margaret W. Neuman*. University of Chicago Press, Chicago. 1958. xi+209 pages. $5.00.

This is, indeed, a most interesting and most provocative book in which the authors attempt to explain many things—occasionally on the basis of somewhat arbitrarily selected premises.

Chapter I, "Solution Chemistry," is a review of some of the principal theories on the behavior of electrolytic solutions. Chapter II, "Solubilities," discusses the application of some of these theories to bone. Here, at least one statement appears (p. 28) that will astonish most physical chemists: "One cannot approach the same *equilibrium* from the two different directions—precipitation and dissolution." (Italics added.) This is an admission, in effect, however, that the system is *not at equilibrium*, an admission that invalidates many of the authors' conclusions which pertain only to equilibrium conditions.

Chapter III, "The Mineral Phase," contains some statements which will astonish mineralogists, including: "It is difficult to attain a clear-cut comprehension of the crystallography of hydroxy apatite when mineralogists themselves do not agree on rather fundamental interpretations." While this reviewer admits that the situation has been somewhat befuddled by a few non-mineralogists, he was not aware of any significant difference of opinion among mineralogists concerning the fundamental crystallography of hydroxyapatite.

A decade or two ago, there was some confusion among mineralogists concerning carbonate apatites, which comprise the mineralogical analogs of tooth and bone substance. The authors, incidentally, do not mention francolite or dahllite, but use the pseudo-mineralogical term "pseudo-apatite" (quoting a non-mineralogist). Geologists will be surprised to learn (p. 42): "Geological

specimens [phosphorites] which are very old and probably formed at *high temperature* can be expected to have few internal defects." (Italics added.)

Other chapters are headed: Surface Chemistry, Skeletal Dynamics, Physiological Regulatory Mechanisms, and Mechanisms of Calcification. From the first chapter until the last, the argument is punctuated with a (Ca^{++}) . a ($HPO_4^{=}$) a very handy activity product, if it were possible to demonstrate a straight-forward relationship to the solid phase present, to the role of enzymes in ossification, to the cellular activity of the osteoblasts, or to several other physiological-chemical processes.

Despite the specific criticisms mentioned above and the authors' admission (p. vii), "By substitution of unconfirmed, preliminary findings and speculation for hard fact, the job was completed," this book represents a commendable effort by Dr. and Mrs. Neuman. The literary excellence of the authors' presentation may mislead persons who are not versed in some of the topics considered—particularly, mineralogy and physical chemistry—because the "hard fact" and "speculation" have been almost irretrievably intermixed.

DUNCAN MCCONNELL

The Atom and the Energy Revolution. *Norman Lansdell.* Philosophical Library, Inc. 200 pp. $6.00.

This book considers only the peaceful uses of energy, including the atom among all possible sources of energy, and supplies facts needed for consideration of such questions as (1) the relation of industry to the state; (2) the effects on world trade; (3) the use of atomic energy to meet expanded needs when other sources of energy have gone to short supply; (4) the effects of atomic energy on the balance between food production and an expanding population.

To reach his desired audience, the business men, citizens and general readers, the author has presented his material in simplified, concise form. He has grouped his facts in nine sections the title of which are listed below as the best way of indicating the scope of the subject and manner of treatment.

I World Energy Resources and Demand.
II New Sources of Energy.
III The Atom and its Energy.
IV Methods of Releasing Atomic Energy.
V Sources of Natural Materials for Atomic Energy Development.
VI The Exploitation of Atomic Energy.
VII Political and Commercial Organizations for Atomic Energy Development
VIII Radiation Risks and Insurance Against Them.
IX The World Impact of Atomic Energy.

The format is good, and a brief glossary adds to the book's usefulness.

THOMAS H. LANGLOIS

Algae: The Grass of Many Waters. *Lewis Hanford Tiffany.* Charles C. Thomas, Pub., Springfield, Illinois. Second Ed. 1958. vii+199 pp., 13 figs., 41 pls.

During the intervening twenty years since the first edition of this book appeared, it has gained recognition as an outstanding contribution to algal literature. The second edition can only enhance this reputation. As the author remarks, "the world has moved along quite rapidly in twenty years," so likewise has the study of algae. Knowledge that did not exist at the time of the first edition has been incorporated by changes in the text and by the addition of a new chapter concerning "Algae and Research." Yet, in rewriting, the author has retained the simplicity and attractive style that appealed to the specialist and nonspecialist alike. In general the book summarizes the existing knowledge of the algae while emphasizing their relationships with people.

CLARENCE E. TAFT

Coastal and Submarine Morphology. *Andre Guilcher.* Translated from French by B. W. Sparks and Rev. R. H. W. Kneese. John Wiley & Sons, Inc. 274 pp. $6.50.

This book, first published in French in 1954, now makes readily available to readers of English the comprehensive studies of a professor of Oceanography at the Sorbonne University. It is divided in two parts, dealing extensively in the first part with coastal geomorphology, and outlining in the second part the field of submarine geomorphology. Each of the five sections of PART I, dealing respectively with the forces in action, shoreline movements, coastal features related to sea action, a classification of coasts, and coastal evolution, is well documented and bears its own bibliography. Part II begins with some history, definitions and general references, and deals adequately with the continental margin and the deep-sea floor. The text is well written but legibility could have been increased by use of larger type. The 8 plates and 40 figures add greatly to the presentation.

THOMAS H. LANGLOIS

PLAN TO ATTEND

Next Annual Meeting

of

THE OHIO ACADEMY OF SCIENCE

Antioch College, Yellow Springs, Ohio

April 21-23, 1960